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PART III

FEDERAL ENERGY ADMINISTRATION

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ENERGY CONSERVATION PROGRAM FOR APPLIANCES

Proposed Test Procedures for Furnaces

FEDERAL ENERGY ADMINISTRATION

[10 CFR Part 430]

ENERGY CONSERVATION PROGRAM FOR APPLIANCES

Proposed Test Procedures for Furnaces; Public Hearing

AGENCY: Federal Energy Administration.

ACTION: Proposed rule.

SUMMARY: The Federal Energy Administration hereby proposes to amend its regulations in order to prescribe test procedures for furnaces under the Energy Policy and Conservation Act. The Act requires that standard methods for testing furnaces be prescribed as part of the energy conservation program for appliances. The intended effect of this proposal is to implement the Act's requirements for the solicitation of public comments before the test procedures are prescribed.

DATES: Comments by September 27, 1977, 4:30 p.m.; requests to speak by September 22, 1977, 4:30 p.m.; statements by September 27, 1977, 4:30 p.m.; hearing to be held on October 4, 1977, at 9:30 a.m.

ADDRESSES: Requests to speak at the hearing to: Executive Communications, Room 3317, Federal Energy Administration, Box NX, Washington, D.C. 20461.

Comments to: Executive Communications, Room 3317, Federal Energy Administration, Washington, D.C. 20461.

HEARING HELD AT: Federal Energy Administration, Federal Building, Room 3000A, 12th and Pennsylvania Avenue NW., Washington, D.C. 20461.

FOR FURTHER INFORMATION CONTACT:

James A. Smith (Program Office), Old Post Office Building, Room 307, 12th and Pennsylvania Avenue NW., Washington, D.C. 20461, 202–566–4635.

Robert C. Gilette (Hearing Procedures), 2000 M Street NW., Room 222A, Washington, D.C. 20461, 202–566–5201.

Jim Merna (Media Relations), 12th and Pennsylvania Avenue NW., Room 3104, Washington, D.C. 20461, 202–566–9833.

Robert D. R. de Sugny (Office of the General Counsel), 12th and Pennsylvania Avenue NW., Room 7146, Washington, D.C. 20461, 202–566–9750.

SUPPLEMENTARY INFORMATION:

A. Background

The Federal Energy Administration (FEA) proposes to amend Chapter II of Title 10, Code of Federal Regulations, in order to prescribe test procedures for furnaces pursuant to section 323 (42 U.S.C. 6293) of the Energy Policy and Conservation Act (Act) (Pub. L. 94–163). The adoption of test procedures does not mean that actual testing must be conducted. The procedures merely establish standard methods for testing when testing is otherwise required by the Act itself or by regulations implementing other parts of the program. For example, the Federal Trade Commission (FTC) may require that all or part of the test procedure be conducted in exercising its appliance energy efficiency labelling authority regarding a particular appliance type.

By notice issued May 10, 1976 (41 FR 19977, May 14, 1976), FEA proposed to establish Part 430, entitled "Energy Conservation Program for Appliances," in Chapter II of Title 10 of the Code of Federal Regulations. That notice proposed a Subpart A to Part 430, containing general program provisions, and a Subpart C, containing proposed energy efficiency improvement targets. By notice issued July 22, 1976 (41 FR 31237, July 27, 1976), FEA proposed an amendment to proposed Part 430 to add a Subpart B which would contain the appliance test procedures required to be prescribed by section 323 of the Act. Subparts A and B were established by notice issued on May 24, 1977 (42 FR 27896, June 1, 1977). A notice was issued July 8, 1977 (42 FR 36648, July 15, 1977) withdrawing the original proposal of Subpart C and reproposing a new Subpart C containing proposed energy efficiency improvement targets for the products listed in 1–10 of section 322(a) of the Act. Proposed energy efficiency improvement targets for the products listed in 11–13 of section 322(a) of the Act will be issued at a later date.

The notice issued on May 24, 1977, included final test procedures for room air conditioners. By notice issued March 17, 1977 (42 FR 15423, March 22, 1977) FEA proposed test procedures for dishwashers. This notice also included certain program definitions which have not yet been finalized. Proposed test procedures for water heaters, television receivers, refrigerators and refrigerator-freezers, freezers and clothes dryers were issued on April 21, 1977 (42 FR 21576 et seq., April 27, 1977). Proposed test procedures for unvented home heating equipment were issued on May 4, 1977 (42 FR 23860, May 11, 1977), and proposed test procedures for automatic and semi-automatic clothes washers were issued on May 11, 1977 (42 FR 25329, May 17, 1977), including a determination that test procedures cannot be developed for any other class of clothes washers. Proposed test procedures for humidifiers and dehumidifiers were issued on May 25, 1977 (42 FR 27941, et seq. June 1, 1977). Proposed test procedures for central air conditioners were issued on June 7, 1977 (42 FR 30401, June 14, 1977), and were followed by proposed test procedures for conventional ranges, cooking tops and ovens, including microwave ovens, which were issued on June 9, 1977 (42 FR 30627, June 16, 1977). The latter notice included a determination to delay the publication of test procedures for any other class of the type "kitchen ranges and ovens." By this notice, FEA is proposing test procedures for furnaces.

Section 323(a)(2) of the Act requires FEA to direct the National Bureau of Standards (NBS) to develop, for specifically named types of covered products, test procedures for the determination of the estimated annual operating costs and at least one other useful measure of energy consumption which FEA determines is likely to assist consumers in making purchasing decisions. Pursuant to the Act, FEA directed NBS to develop test procedures for FEA's use in prescribing test procedures under the Act. As part of this undertaking, NBS evaluated existing test procedures for measuring energy consumption of furnaces.

Current testing and rating requirements for furnaces are described in a number of standards, including: ANSI Z21.47–1973 for gas fueled gravity and forced air central furnaces; ANSI Z91.1–1972 for oil fueled air central furnaces; ARI 280–74 for electric furnaces and boilers; ANSI Z21.13–1974 for gas fueled boilers; and the Hydronic Institute's "Testing and Rating Standard for Cast Iron and Steel Heating Boilers" for oil fueled boilers. These standards measure the steady state efficiency of furnaces but do not account for any part load or seasonal performance effects. In order to estimate the seasonal efficiency and annual operating cost of fossil fuel heating systems, it is necessary to account for the various heating system losses under cyclic or part load operating conditions and for the effect of combustion and draft control air on infiltration. The test procedures and calculation methods formulated by NBS and proposed herein today, utilize portions of the industry standards described above while also accounting for these factors.

Under the requirements of section 32 of the Federal Energy Administration Act of 1974 (15 U.S.C. 761 et. seq.), as amended by section 9 of the Federal Energy Administration Authorization Act of 1977 (Pub. L. 95–70), the Administrator must name the organization which promulgated any commercial standards which were contained in, or authorized ards are incorporated in the proposed rule in the notice of rulemaking. The Administrator is also required to state whether, in his judgement, the named organization complied with the requirements of subsection (b) of section 32. As noted above, various industry standards are incorporated in the propjosedl regulations. It is the judgement of the Administrator that the above named standards did not comply with the requirements of section 32(b), in that the standards were not developed in a manner which provided for public participation, comment, and review. In this rulemaking, FEA is providing interested persons an opportunity to comment on the appropriateness of these standards as used in the furnace test procedure. Comments are specifically requested on any specific changes the person commenting believes are necessary to make the standards appropriate for the purposes of testing furnaces.

Today's proposal adds to § 430.2 a definition of "furnace" and amends the definition in § 430.2 of "Basic model" by adding a subparagraph (14) applying specifically to furnaces. In addition, § 430.2 contains definitions proposed

previously (42 FR 15423, March 12, 1977) some of which are applicable to the test procedures for furnaces. Comments on these definitions are timely as provided below.

B. MEASURES OF ENERGY CONSUMPTION

The Act requires FEA to prescribe test procedures for the determination of estimated annual operating costs and at least one other useful measure of energy consumption which the Administrator determines is likely to assist consumers in making purchasing decisions. The estimated annual operating cost for furnaces in proposed § 430.22(n) is the product of the average annual energy consumption of the furnace and the representative average unit cost of energy.

NBS has developed a method of calculating a typical annual cost of operation for furnaces which takes into account the annual fuel utilization efficiency, the heating load hours, the residence design heat loss, the auxiliary electrical energy used by forced air furnace blower motors, or boiler water pumps, powered burner motors, and the pilot input rate if applicable.

Also proposed in § 430.22(n) are test procedures regarding the estimated annual operating cost by geographic region of the United States, since energy consumption and annual operating cost of furnaces are directly related to geographic location. Annual cost of operation by geographic location may be useful for consumers in making purchasing decisions with respect to furnaces in addition to the single national average value applicable to any specific unit under proposed § 430.22(n). Also proposed in § 430.22(n) are test procedures for calculating annual operating costs for several standardized design heating requirements for each region in order to facilitate the comparison of operating costs of different size furnaces and comparison with heat pumps.

The proposed test procedures for regional costs incorporate a map of the continental United States with regional "heating load hours" for adjusting the representative average use cycle (typical annual usage) of furnaces by geographic location. These regional values of "heating load hours" are based on the average number of degree days and the outdoor design temperature for each region.

An additional proposed measure of energy consumption in § 430.22(n) that is likely to assist consumers in making purchasing decisions is the fuel utilization efficiency. This efficiency is the ratio of the furnace's annual output of useful energy to the annual fuel energy input of the furnace multiplied by 100. The test procedures are designed to measure the fuel utilization efficiency at a part-load operating condition in order to account for both on-cycle energy losses and off-cycle energy losses. Both types of losses can be influenced by furnace design characteristics and features.

On-cycle losses include:

(1) Energy contained in the combustion gases which are discharged outdoors through the flue;

(2) The loss of heated room air used for combustion at the burner and for dilution of hot combustion gases through the draft hood, integral draft diverter, or barometric draft regulator.

Off-cycle losses include:

(3) The loss of heat stored in the metal of the furnace heat exchanger when the burner and circulating warm air blower shuts off.

(4) The loss of heated room air which escapes through the open furnace stack to the outdoors;

(5) Fuel input to a continuously burning gas pilot.

FEA recognizes that there may be additional useful measures of energy consumption for furnaces other than the measures described above. According, today's proposal, in proposed § 430.22(n), provides for the addition of other useful measures which the Administration determines are likely to assist consumers in making purchasing decisions. These measures, however, must be derived from the application of the uniform test methods proposed today as Appendix N to Subpart B. Furnace manufacturers would, if required, only have to perform different computations with the data generated by the existing test methods contained in Appendix N.

C. LABORATORY METHODOLOGY

The proposed test procedures are based upon the heat loss method in which the sensible and latent heat losses through the stack are determined. Since these losses will depend upon such factors as load, cycling rate, chimney height, over sizing, the type of draft control device, the infiltration characteristics of a residence and weather profile, it is desirable to measure in the laboratory, quantities which characterize the performance of a furnace under standardized laboratory test conditions and then to calculate its performance under typical field conditions. This has the advantage of simplifying the amount of experimental laboratory data required and thereby reducing the costs of testing.

The test procedures require measurement of the steady-state performance of a furnace in order to calculate a steady-state efficiency. For furnaces without integral draft diverters, this is accomplished by measurng the steady-state flue gas temperature and the concentration by volume of carbon dioxide in the flue gas. For furnaces utilizing integral draft diverters, the steady-state performance is determined by measuring the steady-state stack gas temperature and the concentration by volume of carbon dioxide in the dry stack gas. This latter method is employed because of the difficulty in accurately measuring flue gas temperatures and concentrations of carbon dioxide in units with integral draft diverters.

The test procedures account for cyclic effects by measuring flue gas temperatures during warm-up from a cold start and cool-down from steady-state operation. As noted above, actual flue gas temperature measurements on furnaces with integral draft diverters are difficult to make, however, for purposes of accounting for transient effects, it was determined that flue gas temperatures could be measured by blocking the draft diverter relief opening, replacing the 5-foot stack with a 2-foot length of flue pipe, and measuring the temperature and CO_2 concentration of the flue gas. The flue gas temperature profiles are determined by making two discrete flue gas temperature measurements during warm-up and three discrete measurements during cool-down. The use of discrete warm-up and cool-down temperature measurements reduces the amount of data required and greatly simplifies the process of data reduction. The times at which these discrete flue gas temperature measurements are made were chosen to minimize the errors involved in calculating the on-cycle losses. As a result, different sets of times are recommended for furnaces and low pressure steam and hot water boilers.

In addition to the above mentioned tests, certain factors, which describe the flow rates through the flue and stack during the on and off-periods, are assigned according to the type of equipment under test. The factor S/F, which is the ratio of stack gas mass flow rate to flue gas mass flow rate under steady-state operation and at an average outdoor temperature of 42F (5.56C), is used to estimate the infiltration losses during both the on and off-cycles. By assigning values which are based upon field data, the need to simulate field conditions in the laboratory (eg. a high chimney, a low outdoor temperature, a typical barometric damper setting, etc.) is avoided. A factor D_F represents the ratio of the gas mass flow rate through the flue during the off-cycle to the gas mass flow rate through the flue during the on-cycle at identical temperatures. A similar quantity, D_S, is the ratio of the stack gas mass flow rates during the on-period to the stack gas mass flow rate during the off-period at identical temperatures. The values of D_F and D_S depend upon whether the system being tested employs a stack damper and/or a power burner. If a unit is equipped with a stack damper, its effectiveness is determined by measuring the amount of stack area which the damper blocks during the off-cycle. Furnaces or low pressure steam and hot water boilers using power burners may employ an assigned power burner factor of $D_P=0.30$ or measure D_P directly by employing a tracer gas to determine the mass flow rate in the flue while the power burner is off.

Wherever possible the test methods recommended herein have been based upon existing consensus standards and procedures presently employed by manufacturers to evaluate the performance of central heating equipment. This was done to reduce the amount of duplicate testing required and to obtain a set of performance tests which would be within the capabilities of the entire furnace industry.

A step-by-step calculation procedure for determing fuel utilization efficiency based upon an average U.S. weather pat-

tern is given in §§ 4.1 and 4.2 for gas and oil-fueled central heating equipment. A worksheet is illustrated which may be used to keep track of the experimental data and the various step-by-step calculations. This efficiency factor is used to estimate the annual cost of operation in different climatic regions and an average operating cost for the country. The technical background, assumptions and equations which form the basis for the fuel utilization efficiency calculation and annual operating cost calculation are contained in Appendix A of the NBS test procedure review document.

Assigned values of the factors S/F, D_F and/or D_S are given in Tables 1 and 2. The factor ϕ is the fraction of combustion and draft control air which contributes to additional residential infiltration and is assumed to equal $.70 for furnaces and low pressure steam and hot water boilers using indoor air. The quantity (1 + a) is the ratio of the furnace steady-state output to the design heating requirement of a typical residence and is set equal to 1.70 for the purpose of calculating a fuel utilization efficiency and an average national operating cost.

The steady-state latent and sensible heat losses and the steady-state efficiency η_{ss}, are also calculated in section 4.2. The flue-gas and stack-gas temperature profiles, corresponding to warm-up from a cold start and cool-down from steady-state operation, are then approximated by simple experimental functions having the form

$$(a\,e^{-t/\tau}+b).$$

The parameters in these functions

$$\tau_{ON},\ \tau_{OFF},\ \theta_{F,0,X},\ \Psi_{F,0,X},\ \Psi_{F,\infty,X},\ \Psi_{S,0,X},\ \text{and}\ \Psi_{S,\infty,X}$$

are determined from the warm-up, cool-down and steady-state flue temperature measurements and are corrected for the effect of cycling to obtain the flue-gas and stack-gas temperature-vs-time profiles which would exist if the unit were operating in the field at a heating load factor equal to 22.5 percent. For outdoor units or units designed to use outdoor air for combustion and draft control, a further adjustment to these profiles is made using a correction factor C_s to account for the fact that the air used for combustion has an average temperature of 42F (5.56C).

The flue-gas and stack-gas temperature-vs-time profiles are employed, along with the factors describing the on and and off-cycle air flow rates, to calculate the dynamic system losses $L_{S,on}$, $L_{S,off}$, $L_{I,on}$, and $L_{I,off}$, at the average heating load factor and the average outdoor temperature of 22.5 percent and 42F (5:56C), respectively. These losses, together with the latent heat loss, jacket loss on outdoor units, and the pilot light loss during the non-heating season, are then used to calculate an annual fuel utilization efficiency, $EFFY_A$.

D. Representative Average Use Cycle

Section 323(b)(2) (42 U.S.C. 6293 (b)(2)) of the Act provides that test procedures for determining estimated annual operating costs of any covered product shall be calculated from measurements of energy use in a representative average-use cycle (as determined by the Administrator) and from representative average unit costs (as provided by the Administrator) needed to operate such product during such cycle. FEA has determined that the representative average-use cycle for furnaces is 2,080 heating load hours per year. This determination is based upon an NBS recommendation to FEA. The NBS recommendation is included in the NBS test procedure review document which is available for inspection as provided for later in this notice.

The average use cycle of 2,080 heating load hours for furnaces was derived in an analysis performed by NBS which considered outdoor temperature data extending over a 25-year period at locations in each of the 48 states in the continental United States and the District of Columbia. In addition, the number of housing units in each state using gas or oil as the primary fuel for heating, as reported in the 1970 U.S. Census, was also used in the analysis.

Using the number of housing units by state as weighting factors, and the average outdoor design temperature at each location, a national average outdoor design temperature was calculated to be 5° F. A similar computation was performed using average annual heating degree day values for each state resulting in a national average of 5,200 heating degree days. The average annual heating load hours was then calculated by multiplying the average number of degree days by 24 and dividing that result by the temperature difference between 65° F and the average outdoor design temperature; the result being 2,080 heating load hours per year.

FEA has developed representative average unit costs of energy needed to calculate the annual operating cost for the representative average use cycle. This information was provided by notice issued July 11, 1977 (42 FR 36549, July 15, 1977).

E. Number of Units To Be Tested

Proposed § 430.23(n) would provide for sampling of each basic model to be tested when testing of furnaces is required by the Act or by program regulations of agencies responsible for administering the Act. This provision is intended both to provide an acceptable level of assurance that test results are applicable to any entire basic model for which testing is required and to minimize the testing burden on manufacturers. FEA believes that the sampling approach proposed today will enable consumers to make meaningful comparisons of information appearing on appliance labels, and also will meet the requirements of section 323(b) of the Act that test procedures not be unduly burdensome to conduct.

Under proposed § 430.23(n), a sample of sufficient size of each basic model would be tested to assure that, for each measure of energy consumption described in § 430.22(n), there is a 95 percent probability that the mean of the values of these measures of the sample is within 5 percent of the true mean of these measures of the basic model. The size of the sample of a particular basic model will depend upon the following factors:

(1) The level of confidence required (set at 95 percent in the proposed regulations);

(2) The maximum allowable difference between the sample mean and the mean of the basic model (expressed in the proposal as a percent of the true mean and set at 5 percent); and

(3) The relationship of the mean and standard deviation of the basic model.

The relationship of the mean and standard deviation of the basic model can be determined from data available to manufacturers. With this information and using standard statistical techniques, manufacturers can determine the number of units required to be tested. In any case, at least 1 unit of each basic model must be tested. Sample units would be selected randomly from the production stream.

Manufacturers and other interested persons are encouraged to comment on the sampling approach. Manufacturers are especially encouraged to submit any data which relates to the size of the samples which the provision would require to be tested. Comments alleging that the sampling provision is burdensome should include a full discussion of the facts upon which such allegation is based.

F. Request for Particular Comments

While FEA is soliciting comments on all aspects of the proposed test procedures for furnaces, FEA is particularly interested in receiving comments on the following subjects:

1. Other useful measures of energy consumption or data on typical consumer usage of furnaces in addition to those proposed today.

2. The appropriateness of incorporating the following proposed sections of ANSI Standards relating to jacket losses of forced air furnaces intended to be installed out-of-doors:

(a) For gas fueled and electric furnaces—ANSI Z 21.47—1973, §§ 2.9.1 and 2.9.2

(b) For oil fueled furnaces—ANSI Z 91.1—1972, Appendix B

3. Definitions already promulgated or proposed in § 430.2 which may affect the testing of furnaces. Comments with respect to such definitions are timely until the close of the written record as specified below.

G. Comment Procedure

1. *Written Comment.* Interested persons are invited to participate in this rulemaking by submitting data, views or arguments with respect to the proposed test procedures for furnaces set forth in

this notice to Executive Communications, Room 3317, Federal Energy Administration, Box NX, Washington, D.C. 20461.

Comments should be identified on the outside of the envelope and on documents submitted to FEA with the designation "FURNACES—Proposed Test Procedures." Fifteen copies should be submitted. All comments received by September 27, 1977, before 4:30 p.m., e.s.t., and all other relevant information, will be considered by FEA before final action is taken on the proposed test procedures.

Any information or data considered confidential by the person furnishing it must be so identified in writing, and only one copy of the information need be submitted. FEA reserves the right to determine the confidential status of the information or data and treat it according to its determination.

2. *Public Hearings.* (a) *Request procedure.* The time and place of the public hearing are indicated at the beginning of this preamble. The hearing will be continued, if necessary, on October 5, 1977.

FEA invites any person who has an interest in the proposed rulemaking issued today, or who is a representative of a group or class of persons that has an interest, to make a written request for an opportunity to make an oral presentation. Such a request should be directed to the address indicated at the beginning of this preamble and must be received before 4:30 p.m., e.s.t., on September 22, 1977. Such a request may be hand delivered to such address, between the hours of 8:00 a.m. and 4:30 p.m., Monday through Friday. A request should be labeled both on the document and on the envelope "FURNACES—Proposed Test Procedures," Box NX.

The person making the request should briefly describe the interest concerned; if appropriate, state why she or he is a proper representative of a group or class of persons that has such an interest; and give a concise summary of the proposed oral presentation and a telephone number where she or he may be contacted through October 4, 1977.

FEA will notify each person selected to appear at the hearing before 4:30 p.m., September 26, 1977. Each person selected to be heard must submit 50 copies of her or his statement to the address and by the date given in the beginning of this preamble. In the event any person wishing to testify cannot meet the 50 copy requirement, alternative arrangements can be made with the Office of Regulations Management in advance of the hearing by so indicating in the letter requesting an oral presentation or by calling the Office of Regulations Management at 202–254–3345.

(b) *Conduct of hearing.* FEA reserves the right to select the persons to be heard at this hearing, to schedule their respective presentations and establish the procedures governing the conduct of the hearing. The length of each presentation may be limited, based on the number of persons requesting to be heard.

An FEA official will be designated to preside at the hearing. This will not be a judicial or evidentiary-type hearing. Questions may be asked only by those conducting the hearing, and there will be no cross-examination of persons presenting statements. Any decision made by FEA with respect to the subject matter of the hearing will be based on all information available to FEA. At the conclusion of all initial oral statements, each person who has made an oral statement will be given the opportunity if she or he so desires, to make a rebuttal statement. The rebuttal statements will be given in the order in which the initial statements were made and will be subject to time limitations.

Any interested person may submit questions to be asked of any person making a statement at the hearing to Executive Communications, Box NX, FEA, before 4:30 p.m., e.s.t., September 27, 1977. FEA will determine whether the question is relevant, and whether the time limitations permit it to be presented for answer.

Any person who makes an oral statement and who wishes to ask a question at the hearing may submit the question, in writing, to the presiding officer. The presiding officer, will determine whether the question is relevant, and whether the time limitations permit it to be presented for answer.

Any further procedural rules needed for the proper conduct of the hearing will be announced by the presiding officer.

A transcript of the hearing will be made and the entire record of the hearing, including the transcript, will be retained by FEA and made available for inspection at the FEA Freedom of Information Office, Room 2107, Federal Building, 12th and Pennsylvania Avenue NW., Washington, D.C., between the hours of 8:00 a.m. and 4:30 p.m., Monday through Friday. Any person may purchase a copy of the transcript from the reporter. A copy of NBS' recommendations concerning test procedures for FURNACES will be made available for inspection at the FEA Freedom of Information Office.

H. Environmental and Inflationary Review

As required by section 7(c)(2) of the Federal Energy Administration Act of 1974 (Pub. L. 93–275), a copy of this notice has been submitted to the Administrator of the Environmental Protection Agency for this comments concerning the impact of this proposal on the quality of the environment. The Administrator has no comments.

The National Environmental Policy Act of 1969 requires FEA to assess the environmental impacts of any proposal by the Agency for "major Federal actions significantly affecting the quality of the human environment." Since test procedures under the conservation program for appliances will be used only to standardize the measurement of energy usage and will not affect the quantity or distribution of energy usage, FEA has determined that the action of prescribing test procedures, by itself, will not result in any environmental impacts. On this basis, FEA has determined that, with respect to prescribing test procedures under the conservation program for appliances, no environmental impact statement is required.

The proposal has been reviewed in accordance with Executive Order 11821 as amended by Executive Order 11949, and OMB Circular No. A–107 and has been determined not to be a major proposal requiring evaluation of its economic impact as provided for therein.

(Energy Policy and Conservation Act, Pub. L. 94–163, as amended by Pub. L. 94–385; Federal Energy Administration Act of 1974, Pub. L. 93–275, as amended by Pub. L. 94–385; E.O. 11790, 39 FR 23185.)

In consideration of the foregoing, it is proposed to amend Chapter II of Title 10, Code of Federal Regulations, as set forth below.

Issued in Washington, D.C., July 28, 1977.

Eric J. Fygi,
Acting General Counsel,
Federal Energy Administration.

1. Section 430.2 is amended by adding a subparagraph (14) as part of the definition of "Basic model" and by adding the definitions of "furnace," "forced air central furnace," "gravity central furnace," "electric central furnace," "low pressure steam or hot water boiler," "electric boiler," and "direct vent system," to read as follows:

§ 430.2 Definitions.

* * * * *

"Basic model" means all units of a given type of covered product manufactured by one manufacturer and—

* * * * *

(14) With respect to furnaces, having the same primary energy source and essentially identical functional physical and electric characteristics.

* * * * *

"Furnace" means a device designed to be the principal heating source for the living space of a residence having a heat input rate less than 400,000 Btu's per hour, and includes forced air central furnace, gravity central furnace, electric central furnace, electric boiler, and low pressure steam or hot water boiler.

"Forced air central furnace" means a gas or oil burning furnace designed to supply heat through a system of ducts with air as the heating medium. The heat generated by combustion of gas or oil is transferred to the air within a casing by conduction through heat exchange surfaces and is circulated through the duct system by means of a fan or blower.

"Gravity central furnace" means a gas fueled furnace which depends primarily on natural convection for circulation of heated air and which is designed to be used in conjunction with a system of ducts.

"Electric central furnace" means a furnace designed to supply heat through a system of ducts with air as the heating medium, and in which heat is generated by one or more electric resistance heat-

ing elements and the heated air is circulated by means of a fan or blower.

"Direct vent system" means a system supplied by a manufacturer which provides outdoor air directly to a furnace for combustion and draft relief, if the unit is so equipped.

"Electric boiler' means an electrically powered furnace designed to supply low pressure steam or hot water for space heating application. A low pressure steam boiler operates at or below 15 psig steam pressure; a hot water boiler operates at or below 160 psig water pressure and 250° F water temperature.

"Low pressure steam or hot water boiler" means a gas or oil burning furnace designed to supply low pressure steam or hot water for space heating application. A low pressure steam boiler operates at or below 15 psig steam pressure; a hot water boiler operates at or below 160 psig water pressure and 250° F water temperature.

2. Section 430.22 is amended by adding paragraph (n), to read as follows:

§ 430.22 Test procedures for measures of energy consumption.

* * * * *

(n) *Furnaces.* (1) The estimated annual operating costs for furnaces shall be the sum of: (A) the product of the average annual fuel energy consumption in Btu's per year for gas or oil furnaces and in kilowatt-hours per year for electric furnaces, determined according to 4.8 and 4.10 of Appendix N of this subpart, respectively, and the representative average unit cost in dollars per Btu for gas or oil, or dollars per kilowatt-hour for electric, as appropriate, as provided by the Administrator plus (B) the product of the average annual auxiliary electric energy consumption in kilowatt-hours per year, determined according to 4.9 of Appendix N of this subpart, and the representative average unit cost in dollars per kilowatt-hour as provided by the Administrator, the resulting sum then being rounded off to the nearest dollar per year.

(2) The annual fuel utilization efficiency for furnaces, expressed in percent, shall be the ratio of annual output of useful energy delivered to the heated space to the annual fuel energy input to the furnace determined according to 4.2.33 of Appendix N of this subpart.

(3) The estimated regional annual operating costs for furnaces computed for minimum or maximum standardized design heating requirements shall be the sum of: (A) the product of the regional annual fuel energy consumption for the minimum or maximum standardized design heating requirement in Btu's per year for gas or oil furnaces and in kilowatt-hours per year for electric furnaces, determined according to 4.19, 4.20, 4.23, or 4.24, of Appendix N of this subpart, respectively, and the reprsentative average unit cost in dollars per Btu for gas or oil, or dollars per kilowatt-hour for electric, as appropriate, as provided by the Administrator plus (B) the product of the regional annual auxiliary electrical energy consumption in kilowatt-hours per year determined according to 4.21 or 4.22 of Appendix N of this subpart, and the representative average unit cost in dollars per kilowatt-hour as provided by the Administrator, the resulting sum then being rounded off to the nearest dollar per year.

(4) The estimated regional annual operating cost for furnaces shall be the sum of: (A) the product of the regional annual fuel energy consumption in Btu's per year for gas or oil furnaces and in kilowatt-hours per year for electric furnaces, determined according to 4.12 and 4.14 of Appendix N of this subpart, respectively, and the representative average unit cost in dollars per Btu for gas or oil, or dollars per kilowatt-hour for electric, as appropriate, as provided by the Administrator plus (B) the product of the regional auxiliary electrical energy consumption in kilowatt-hours per year, determined according to 4.13 of appendix N of this subpart, and the representative average unit cost in dollars per kilowatt-hour as provided by the Administrator, the resulting sum then being rounded off to the nearest dollar per year.

(5) Other useful measures of energy consumption for furnaces shall be those measures of energy consumption which the Administrator determines are likely to assist consumers in making purchasing decisions and which are derived from the application of Appendix N of this subpart.

3. Section 430.23 is amended by adding a paragraph (n) to read as follows:

§ 430.23 Units to be tested.

* * * * *

(n) *Furnaces.* (1) When testing of furnaces is required for a measure or measures of energy consumption described in 430.22(n) of this subpart, a sample of sufficient size of each basic model shall be tested to ensure that, for each such measure of energy consumption, there is a 95 percent probability that the mean of the sample is within 5 percent of the true mean of such measures of the basic model, except that a minimum of 1 unit of each basic model shall be tested.

(2) The sample selected for paragraph (n)(1) of this section shall be a simple random sample drawn from the production stream of the basic model being tested.

(3) A basic model having dual voltage ratings shall be separately tested at each design voltage such that the requirements of paragraph (n)(1) of this section is satisfied at each rating.

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APPENDIX N—UNIFORM TEST METHOD FOR MEASURING THE ENERGY CONSUMPTION OF FURNACES

1.0 DEFINITIONS

1.1 "Steady-state conditions for forced air or gravity central furnaces" means equilibrium conditions in the flue gas as indicated by temperature changes of not more than plus or minus 5° F (2.8° C) in three successive temperature readings taken 15 minutes apart.

1.2 "Steady-state conditions for low pressure steam and hot water boilers" means equilibrium conditions during operation as indicated by temperature changes of not more than 5° F (2.8° C) in the flue gas temperature, and either 4° F (2.2° C) in the outlet water temperature for hot water boilers, or 7° F (3.9° C) in the outlet steam temperature for low pressure steam boilers, in three successive temperature readings taken 15 minutes apart.

1.3 "Flue gases" means reaction products resulting from the combustion of a fuel with the oxygen of the air, including the inerts and any excess air.

1.4 "Excess air" means air which passes through the combustion chamber and the furnace flues in excess of that which is theoretically required for complete combustion.

1.5 "Flue" means a conduit between the flue outlet of the furnace and the draft hood or barometric draft regulator through which the flue gases pass prior to the point of draft relief.

1.6 "Flue outlet" means the opening provided in a furnace for the exhaust of the flue gases from the combustion chamber.

1.7 "Flue losses" means the sum of sensible and latent heat losses above room temperature (70° F) of the flue gases leaving the furnace.

1.8 "Stack" means the portion of the exhaust system downstream of the draft hood or barometric draft regulator.

1.9 "Stack gases" means the flue gases combined with dilution air that enters at the draft hood, integral draft diverter, or barometric draft regulator.

1.10 "Barometric draft regulator" means a device designed to maintain a constant draft in a furnace or boiler.

1.11 "Air shutter" means an adjustable device for varying the size of the primary air inlet(s) to the combustion chamber.

1.12 "Power burner" means a furnace burner which supplies either gas or air or both at pressures exceeding, for gas, the line pressure, and for air, atmospheric pressure, or a burner which depends on the draft induced by a fan for proper operation.

1.13 "Vent limiter" means a device which limits the flow of air from the atmospheric diaphragm chamber of a gas pressure regulator to the atmosphere. A vent limiter may be a limiting orifice or other limiting device.

1.14 "Exhaust/air intake terminal" means a device which is located on the outside of a building and is connected to a furnace by a system of vents. It is composed of an air intake terminal through which the air for combustion is taken from the outside atmosphere, and an exhaust terminal from which flue gases are discharged.

1.15 "Heating element" means the electrical conducting medium which is intended to be heated by an electric current and which dissipates this heat into the air stream.

1.16 "Induced draft" means a method of drawing air into the combustion chamber by mechanical means.

1.17 "Plenum" means an air compartment, that is attached to, or is an integral part of, a forced air furnance and which is designed to either distribute the heated air after it leaves the heat exchanger in the case of a supply plenum, or collects the air which enters the return inlet in the case of a return plenum.

1.18 "Heat input" (Q_{in}) means the rate of energy supplied in a fuel to a furnace, operating under steady state conditions, expressed in Btu's per hour. It includes any input energy to the pilot light and is obtained by multiplying the measured rate of fuel consumption by the measured higher heating value of the fuel.

1.19 "Draft hood" means a device made a part of the stack from a furnace, which is designed to (1) provide for the exhaust of the products of combustion in the event of no draft, back draft, or stoppage beyond the draft hood, (2) prevent a back draft from entering the furnace, and (3) neutralize the effect of stack action of the chimney or gas vent upon the operation of the furnace.

1.20 "Higher heating value" (*HHV*) means the heat produced per unit of fuel when complete combustion takes place at constant pressure and the products of combustion are cooled to the initial temperature of the fuel and air and when the water vapor formed during combustion is condensed. The higher heating value is expressed in Btu's per pound, Btu's per cubic foot for gaseous fuel, or Btu's per gallon for liquid fuel.

1.21 "Integral draft diverter" means a device which is an integral part of a furnace, which is designed to (1) provide for the exhaust of the products of combustion in the event of no draft, back draft, or stoppage beyond the draft diverter, (2) prevent a back draft from entering the furnace, (3) neutralize the effect of stack action of the chimney or gas vent upon the operation of the furnace.

2.0 TESTING CONDITIONS

2.1 *Installation of Test Plenum, Duct Work, and Piping*

2.1.1 Gravity Central Furnaces (Including Direct Vent Systems)

Gravity central furnaces shall be installed and equipped with a vertical supply test plenum or extended casing and horizontal test ducts as described in Section 2.9.1 of ANSI Standard Z21.47-1973.

2.1.2 Forced Air Central Furnaces (Including Direct Vent Systems)

Gas-fueled forced air central furnaces shall be equipped with a plenum and test duct as described in Sections 2.1.9 and 2.1.10 of ANSI Standard Z21.47-1973. Oil fueled forced air central furnaces shall be equipped with a plenum and test duct as described in Section 6.2 of ANSI Standard Z91.1-1972.

2.1.3 Low Pressure Steam and Hot Water Boilers (Including Direct Vent Systems)

Install gas-fueled low pressure steam and hot water boilers as prescribed in Section 2.9 of ANSI Standard Z21.13, 1974. Install oil-fueled low pressure steam and hot water boilers as prescribed in Sections 7.0 and 8.1.1 through 8.1.3 of the Hydronic Institute Testing and Rating Standard for Cast Iron and Steel Heating Boilers, January 1977.

2.1.4 Electric Central Furnaces

Install equipment for testing in accordance with ARI Standard 280-74, Section 4 and Figure 1.

2.1.5 Electric Boilers

Install equipment in accordance with manufacturer's instructions.

2.2 *Flue and Stack Requirements*

2.1.1 Gravity and Forced Air Central Furnaces

2.2.1.1 Gravity and gas fueled forced air central furnaces employing integral draft diverters.

For the steady state performance test described below, gravity and gas fueled forced air central furnaces employing integral draft diverters with vertically discharging furnace outlets shall have attached to and vertically above the outlet, a stack having a diameter the same size as the outlet and shall be covered with insulation having an R value of not less than 7 (°F−HR−Ft²/Btu) and an outer layer of aluminium foil. The stack shall extend not less than 5 feet nor more than five feet six inches above the highest point of the outlet. Furnaces having a horizontally discharging furnace outlet shall have attached an insulated 90 degree elbow, the same size as the outlet, and sufficient vertical insulated black iron pipe so that the outlet is not less than five feet nor more than five feet six inches above the highest point of the furnace outlet. The stack and elbow shall be covered with insulation having an R value of not less than 7 (°F−HR−Ft²/Btu) and an outer layer of aluminum foil.

A two foot long insulated flue pipe shall be used for gas units having vertically discharging flue outlets in the tests for measuring flue temperatures during warm-up and cool-down. The flue pipe shall be covered with insulation having an R value of not less than 7 (°F−HR−Ft²/Btu) and an outer layer of aluminum foil.

2.2.1.2. Gravity and gas fueled forced air central furnaces which do not employ integral draft diverters.

Gravity and gas fueled forced air central furnaces which do not employ integral draft diverters shall have a two foot long insulated flue pipe attached to the vertically discharging flue outlet for the steady state test and tests to measure flue temperatures during warm-up and cool-down. For units having a horizontally discharging flue outlet, an elbow and a two foot long vertical insulated flue pipe shall be attached to the outlet. All insulation shall have an R value not less than 7 (°F−HR−Ft²/Btu) and an outer layer of aluminum foil.

2.2.1.3. Oil fueled forced air central furnaces.

Flue connections for oil fueled forced air central furnaces are to be as described in Figures 1 and 2 of ANSI Standard Z91.1-1972. There shall be no opening on the oil furnace between the furnace and the point where the flue gas sample is to be taken of the flue gas temperature is to be measured. If a barometric draft regulator is incorporated in the furnace, it shall be sealed during all tests.

2.2.2 Low Pressure Steam and Hot Water Boilers (not including direct vent systems)

Gas fueled low pressure steam and hot water boilers employing draft hoods shall have such hoods in place during all performance tests.

Flue connections for low pressure steam and hot water boilers are described in the Hydronic Institute Standard "Testing and Rating Standard for Cast Iron and Steel Heating Boilers," Section 7.2.

2.2.3 Direct Vent Systems

The exhaust/air intake system supplied by the manufacturer shall be in place during all tests. A furnace employing a direct vent system shall not be connected to a chimney or induced draft source, but shall depend for venting of exhaust gases solely on the provision for venting incorporated in the furnace and the exhaust/air intake system supplied with it. On units which are not designed to preheat the incoming air, the first 18 inches of vent pipe downstream of the furnace outlet shall be insulated with a layer of insulation having an R value of 7 (°F−HR−Ft²/Btu) and the insulation material covered by a layer of aluminum foil.

2.3 *Fuel Supply*

2.3.1 Natural Gas

For a furnace utilizing natural gas, maintain the gas supply to the unit under test at a normal inlet test pressure immediately ahead of all controls at 7 to 10 inches water column. The regulator outlet pressure at normal test pressure shall be approximately that recommended by the manufacturer. Use natural gas having a specific gravity of approximately 0.6 and a higher heating value within ±5 percent of 1,025 Btu per standard cubic foot. Determine the actual higher heating value in Btu's per standard cubic foot for the natural gas to be used in the test with an error no greater than one percent.

2.3.2 Propane Gas

For a furnace utilizing propane gas, maintain the gas supply to the unit under test at a normal inlet pressure of 11 to 13 inches water column. The regulator outlet pressure at normal test pressure shall be approximately that recommended by the manufacturer. Use propane HD-5 having a specific gravity of approximately 1.55 and a higher heating value within ±5 percent of 2,500 Btu's per standard cubic foot. Determine the actual higher heating value in Btu's per standard cubic foot for the propane to be used in the test with an error no greater than one percent.

2.3.3 Other Test Gas

The characteristics of other test gases shall be maintained as described in Section 2.2, Table VII, of ANSI Standard Z21.47. Their measured higher heating value shall be within ±5 percent of the values specified in the above ANSI standard.

2.3.4 Oil Supply

For a furnace utilizing fuel oil, the fuel oil used shall be No. 2 fuel oil and shall conform to the specifications outlined in Tables 2 and 3 of ANSI Standard Z91.1-1972. The higher heating value of the test fuel oil shall be measured with an error no greater than one percent.

2.3.5 Electrical Supply

For an electric furnace or boiler, or for an auxiliary electric component of a gas or oil fueled furnace, maintain the electrical supply to the test unit within one percent of the nameplate voltage for the entire portion of the test cycle. If a voltage range is used for nameplate voltage, maintain the electrical supply within one percent of the center of the nameplate voltage range.

2.4 *Burner Adjustments*

2.4.1 Gas Burner Adjustments

Burners of gas fueled furnaces shall be adjusted to their maximum Btu ratings at normal test pressure. All such adjustments shall be within ±2 percent of the hourly Btu rating specified by the manufacturer as measured after 15 minutes of operation starting with all parts of the furnace at room temperature. The primary air shutters shall be set at the maximum opening, correct burner input flow rate to standard conditions of 60° F and 30 inches mercury barometric pressure.

If a vent limiting means is provided on a gas pressure regulator, it shall be in place during all tests.

2.4.2 Oil Burner Adjustments

The burners of oil fueled furnaces shall be adjusted to give the best CO_2 reading and an hourly Btu input during the steady-state performance test described below which is within plus or minus 2 percent of the furnace manufacturer's specified normal hourly Btu input rating. Smoke in the flue shall not exceed a No. 2 smoke during the steady-state performance test as measured by the procedure in ANSI Standard Z11.182-1965 (R1971) (ASTM D 2156-65(1970)). The average draft over the fire and in the flue during the steady-state performance test shall be that recommended by the manufacturer and draft fluctuations shall not exceed 0.005 inches of water gauge. No additional adjustments to the burner shall be made during the required series of performance tests. The instruments and measuring apparatus for this test are described in Section 6.3 of ANSI Standard Z91.1-1972.

2.5 *Circulating Air, Steam, or Water Flow Adjustments*

2.5.1 Gas Fueled Forced Air Central Furnaces (including direct vent systems)

The external static pressure and air flow rate shall be adjusted as specified in Sections 2.1.11, 2.1.12, and 2.1.13 of ANSI Standard Z21.47-1973. Outlet air temperature shall be measured in accordance with Section 2.9.1 of the same standard.

2.5.2 Gravity Central Furnaces

The air flow rate through the furnace shall be such that the average normal air temperature rise at steady-state is not greater than 130°F above the inlet air temperature when the furnace is equipped with the vertical test plenum or extended casing and horizontal test ducts as described in Section 2.9.1 of ANSI Standard Z21.47-1973. Measure the outlet air temperature as specified in Section 2.9.1 of the above standard. The inlet air temperature shall be measured at the center of the plane of each inlet air opening by means of single No. 24 AWG lead type thermocouple, suitably shielded from direct radiation.

2.5.3 Oil Fueled Forced Air Central Furnaces

The external static pressure and air throughput rate shall be adjusted as specified in Table 5 and Section 6.2 of ANSI Standard Z91.1-1972.

2.5.4 Gas Fueled Low Pressure Steam and Hot Water Boilers

Circulating water or steam flow shall be adjusted to obtain the operating conditions of steam or water described in ANSI Standard Z21.13-1974, Section 2.9.

2.5.5 Oil Fueled Low Pressure Steam and Hot Water Boilers

The water flow rate for hot water boilers shall be adjusted to produce a water temperature rise, during steady-state operation, between 120° F (48.9 C) and 165° F (73.9° C) and an outlet water temperature of 200° F (93.3° C) plus or minus 5° F (2.8° C).

2.5.6 Electric Central Furnaces

Use the air quantity and pressures specified by ARI Standard 280-74, sections 7.2.1 and 6.2.3.

2.5.7 Electric Boilers

The flow of water or steam shall be as specified in Section 2.5.4.

2.6 *Thermocouple Installation*

2.6.1 Gravity and Gas Fueled Forced Air Central Furnaces and Low Pressure Steam and Hot Water Boilers

For units employing an integral draft diverter, install nine thermocouples in a horizontal plane in the five foot stack at 4 ft. 6 in. above the highest point of the furnace outlet.

Install one thermocouple in the center of the stack. Install eight thermocouples along imaginery lines intersecting at right angles in this horizontal plane at points one third and two thirds of the distance between the center of the pipe and the pipe wall. Install one thermocouple in the center of the 2 ft. length of insulated flue pipe at the midpoint (i.e., one ft. from the end).

For units which do not employ an integral draft diverter, install nine thermocouples in a horizontal plane 12 inches from the outlet of the 2 foot length of insulated flue pipe. Install one thermocouple in the center of the flue pipe and eight thermocouples along imaginery lines intersecting at right angles in this horizontal plane at points one third and two thirds of the distance between the center of the flue pipe and the flue pipe wall.

Use bead-type thermocouples having wire size not greater than No. 24 American Wire Gauge (AWG).

The locations of thermocouples used for measuring conditioned warm air are described in ANSI Z21.47-1973, Section 2.9. The temperature of the inlet air shall be established by means of a single No. 24 AWG bead-type thermocouple, suitably shielded from direct radiation and located in the center for the plane of each inlet air opening.

2.6.2 Oil Fueled Forced Air Central Furnaces

Thermocouples shall be installed as described in Section 6.3 of ANSI Standard Z91.1-1972 and as shown in Figures 2 and 3 of the same standard using thermocouple wire not larger than 24 AWG.

2.6.3 Gas Fueled Low Pressure Steam and Hot Water Boilers with Direct Vent Systems

Install thermocouples using the following procedures: on direct vent units which preheat the incoming combustion air, two lines intersecting at right angles shall be established inside the vent pipe in a plane parallel to and one inch (25.4 mm) from the outlet of the vent pipe. On direct vent units which do not preheat the incoming combustion air, two lines intersecting at right angles shall be established inside the vent pipe in a plane located within 12 inches of the boiler outlet. These two lines shall be oriented so that they will divide the internal area into quadrants. One thermocouple shall be placed at the intersection of the two lines. Eight thermocouples shall be placed in sets of four along each line at points one third and two thirds of the distance from the intersection to the periphery. Use bead-type thermocouples, not larger than 24 AWG.

2.6.4 Oil Fueled Low Pressure Steam and Hot Water Boilers

Flue pipe and gas temperature instrumentation shall be in accordance with the Hydronic Institute "Testing and Rating Standard for Cast Iron and Steel Heating Boilers," January 1977.

2.6.5 Forced Air Central Furnaces with Direct Vent Systems

For units that are designed to preheat combustion air, install nine thermocouples along two imaginary lines intersecting at right angles inside the vent pipe in a plane parallel to and one inch (25.4 mm) from the outlet of the vent pipe. The lines shall be oriented so that they will divide the internal area into quadrants. One thermocouple shall be located at the intersection of the two lines. Eight thermocouples shall be located in sets of two along each line at points one third and two thirds of the distance from the intersection to the periphery. Use bead-type thermocouples not larger than 24 AWG, at the specified locations. Thermocouples and their locations used for measuring conditioned warm air are described in ANSI Z21.47-1973, Section 2.9.

For units not designed to preheat combustion air, locate the nine thermocouples in a place one foot from the outlet of the furnace and in the configuration described above.

2.7 *Combustion Measurement Instrumentation*

The samples of stack and flue gases for furnaces shall be analyzed to determine the concentration by volume of carbon dioxide present in the dry stack and flue gas with instrumentation which will result in a reading having an accuracy of ±3 percent.

2.8 *Energy Flow Instrumentation*

Install one or more energy flow instruments, which measure the quantity of electrical energy, gas flow, or fuel oil supplied to the furnace, as appropriate, with an error no greater than one percent.

2.9 *Room Ambient Temperature*

Maintain the test room at an ambient air temperature between 65° F and 78° F. Use the procedure outlined in Section 2.1.14 of ANSI Standard Z21.47–1973 to measure room temperature.

2.10 *Equipment Used to Measure Mass Flow Rate in Flue and Stack*

The tracer gas chosen for this task should have a density which is approximately equal to the density of air. It shall be of different chemical species or different concentration from the flue gas to be measured and shall be unreactive with the environment to be encountered. Instrumentation used to measure the concentration of tracer gas may be either the batch or continuous type with an accuracy of ±2 percent of the value of the concentration measured.

3.0 TESTING AND MEASUREMENTS

3.1 *Steady-State Testing*

3.1.1 Gravity and Gas Fueled Forced Air Central Furnaces

3.1.1.1 Stack Gas Temperature and CO_2 Measurements.

The following procedure is only to be used for gravity and gas fueled forced air central furnaces with integral draft diverters.

The furnace shall be set up as specified in 2.1.1. or 2.1.2, 2.2.1 and 2.3.1–2.3.3. Begin the steady-state performance test by operating the burner and the circulating air blower with the adjustments specified by 2.4.1 and 2.5.1 until a steady-state temperature is attained in the stack gas as measured by the center thermocouple located in the 5 foot stack as specifiedin 2.6.1.

Record the steady-state stack gas temperature ($T_{F,ss,s}$). Measure a sample of dry stack gasses for CO_2 ($X_{CO_2,s}$) in accordance with the method of test prescribed in ANSI Z21.47–1973, sections 2.9.1 and 2.9.2 and record. Measure heat input rate (Q_{in}) including the pilot input and the electrical power input at steady-state conditions and record.

The steady-state heat input rate (Q_{in}) including pilot gas shall be determined by multiplying the measured higher heating value of the test gas by the steady-state gas input rate corrected to standard conditions of 60° F and 30 inches mercury.

Measure the steady-state electric power to the circulating air blower (*BE*) and to the power burner (*PE*) on units so equipped and record the data.

3.1.1.2 Flue Gas Temperature and CO_2 Measurements.

After the above test measurements have been completed on units employing integral draft diverters, the 5 to 5½ foot long black iron pipe used in the steady-state test shall be removed, the draft diverter relief opening shall be blocked and a 2 foot length of flue pipe installed as described in section 2.6.1. A single bead-type thermocouple not larger than No. 24 AWG shall be located in the center of the flue pipe and 12 inches from its top. After equilibrium conditions are again achieved, as indicated by changes in the flue gas temperature of not more than 3° F (2.8° C) between readings 15 minutes apart, the steady-state flue gas temperature ($T_{F,ss}$) shall be measured using this single thermocouple and a sample of the flue gases shall be taken in the same plane of measurement. The sample of the flue gases shall be analyzed to determine the concentration by volume of CO_2($X_{CO_2,F}$) present in the dry flue gas.

On units not employing integral draft diverters, the steady-state flue gas temperature shall be measured in the 2 foot length of flue pipe as described in section 2.6 and a sample of the flue gas shall be taken in the plane of measurement. The sample of flue gases shall be analyzed to determine the concentration of CO_2($X_{CO_2,F}$) present in the dry flue gas.

3.1.2 Gas Fueled Forced Air Central Furnaces with Direct Vent Systems

The furnace shall be set up and adjusted as specified in sections 2.1.2, 2.2.1, 2.3.1–2.3.3, and 2.5.1. Flue temperature ($T_{F,ss}$) and CO_2($X_{CO_2,F}$) measurements shall be performed at steady-state conditions as prescribed in

3.1.1. with the following exception:

Temperature measurements shall be made at a location which is determined by the design provisions of the furnace for preheating the incoming air as prescribed in section 2.6.1 for thermocouple location.

3.1.3 Oil fueled Forced Air Central Furnaces (not including direct vent systems)

The furnace shall be set up and adjusted as specified in sections 2.1.2, 2.2.1 and 2.3.4. Begin the steady-state performance test by operating the burner and the circulating air blower with the adjustments specified by 2.4.2 and 2.5.3. When steady-state temperature ($T_{F,ss}$) is attained in the flue gas, measure the average flue gas temperature and measure CO_2($X_{CO_2,F}$) in a sample of the flue gas at the location described in ANSI Standard Z91.1, section 6.5 and record the data. There shall be no opening between the furnace and the point where the flue gas sample is to be measured. If a barometric draft regulator is incurporated in the furnace, it shall be sealed during all tests.

Measure and record the steady-state heat input rate (Q_{in}). Measure steady-state electrical power to the air blower (*BE*) and to the power burner (*PE*) and record these data.

3.1.4 Oil Fueled Forced Air Central Furnaces with Direct Vent Systems

Perform the measurements as prescribed in 3.1.3. Provisions of 3.1.3 apply with the following exceptions:

The equipment used for testing shall be specified in 2.2.3 and the installation of duct work shall be as specified by the manufacturer. In addition, furnaces using outdoor air for combustion and draft control and which preheat the incoming combustion air shall have the steady-state concentration of carbon dioxide in the flue gases ($X_{CO_2,F}$), the steady-state flue gas temperature ($T_{F,ss}$) measured at a location which is different from that shown in Figure 2 of ANSI Standard Z91.1–1972. These measurements shall be made close to the outlet of the vent pipe on furnaces with direct vent systems which preheat the incoming air and just upstream of the barometric draft control on units which use out door air for combustion and draft control and which preheat the incoming air. The procedures and instruments for making these measurements shall, however, be the same as those described in section 2.1.3 of ANSI Z91.1–1972, except insulation is required on surfaces of the exhaust/air intake system exposed to ambient air where surface temperatures exceed the room temperature by more than 30° F (16.7° C).

3.1.5 Gas Fueled Low Pressure Steam and Hot Water Boilers

The boiler shall be set up and adjusted as specified in sections 2.1.3, 2.2.2, or 2.2.3, 2.3.1, 2.3.3, 2.6.3, 2.4.1 and 2.5.4. Begin the steady-state test by operating the burner as specified in section 2.4.1 and the steam or hot water adjusted as specified in section 2.5.4. When steady-state conditions are attained, the flue gas temperature ($T_{F,ss}$) and a sample of the dry flue gases shall be measured for the CO_2 concentration ($X_{CO_2,F}$) at a location in accordance with ANSI Z21.13–1974, section 2.19, and the values recorded. Measure the steady-state electrical power input (*BE* and *PE*) and heat input rate (Q_{in}), including pilot gas. Measure gas temperature and pressure at the meter and barometric pressure and correct the metered gas flow rate to standard conditions of 60° F and 30 inches mercury. Determine the fuel input in Btu per hour using the higher heating value of the fuel.

3.1.6 Oil Fueled Low Pressure Steam and Hot Water Boilers

The boiler shall be set and adjusted as specified in sections 2.1.3, 2.2.2, or 2.2.3, 2.3.4, 2.4.2, and 2.6.4. Begin the steady-state test by operating the burner as specified in section 2.4.2 and adjust the steam or hot water as specified in section 2.5.5. When steady-state conditions are achieved sample the dry flue gases and analyze for CO_2 ($X_{CO_2,F}$). Measure the steady-state flue temperature ($T_{F,ss}$). Measure the steady-state fuel input rate and the steady-state electrical input power (*BE* and *PE*). Determine the measured heat input rate in Btu's per hour (Q_{in}) using the higher heating value (*HHV*) of the fuel oil and the measured steady-state fuel input rate. Record all values measured.

3.1.7 Electric Forced Air Central Furnaces

The steady-state test for electric furnaces is a measurement of the rated power input (E_{in}), in accordance with the test procedure specified in ARI Standard 290–74, section 5.1. All measurements taken shall be at the standard rating condition described in 6.2.1 of Standard 280–74.

3.1.8 Electric boilers

Flow conditions shall be as specified in section 2.5.7. Electrical power input shall be as specified in section 2.3.5.

3.2 *Flue Temperature Measurements—Cool Down Test*

3.2.1 Gravity and Gas Fueled Forced Air Central Furnaces

After steady-state testing is completed, all units with and without integral draft diverters shall have the main burner turned off and the flue gas temperature measured by means of the thermocouple described above, at 1.5 ($T_{F,\ OFF\ (t_2)}$) and 9.0 ($T_{F,\ OFF\ (t_4)}$) minutes after the burner shuts off. Units employing both integral draft diverters and stack dampers shall have the damper control bypassed so that the damper remains open during the cool down test. During this off-period the indoor air circulating blower shall be made to operate during the first three minutes of the off period and shall then be turned off unless the furnace employs a single motor to drive a power burner and an indoor air circulating blower in which case both shall be turned off together. The main burner(s) shall remain off until equilibrium conditions are attained, as indicated by temperature changes in the flue gas of not more than 3° F (2.8° C) between readings 15 minutes apart. For unit employing a continuously burning pilot light, a third flue gas temperature measurement shall then be made to determine the off-period minimum flue gas temperature ($T_{F,\ OFF,(\infty)}$). For units not employing a continuously burning pilot light, $T_{F,\ OFF\ (\infty)}$ is assumed to equal 70° F (21.1° C). During this cool down test, the energy input rate to the pilot light (Q_p), if the unit is so equipped, shall also be measured to within an accuracy of ±3 percent. Record all measured values. For oil fueled units not equipped with stack dampers, a means shall be provided to maintain the draft in the flue within ±0.01 inches of water gauge of the average value measured in the steady-state performance test.

3.2.2 Gravity and Gas Fueled Forced Air Central Furnaces (including direct vent systems)

After steady-state testing has been completed, turn the main burner off and measure the flue gas temperature at 1.5 ($T_{F,\ OFF\ (t_2)}$) and 9.0 ($T_{F,\ OFF\ (t_4)}$) minutes after the burner is shut off using a single bead-type thermocouple, not larger than 24 AWG, located in the center of the flue pipe and the locations prescribed in section 2.6.5. During this off-period, the indoor air circulating blower shall be made to operate during the first 3 minutes of the off-period and shall then be shut off unless the furnace employs a single motor to drive a power burner and an indoor air circulating blower, in which case both shall be turned off. The main burner(s) shall remain off until equilibrium conditions are attained, as indicated by temperature changes in the flue gas temperature of not more than 3° F (2.8° C) between readings 15 minutes apart. For units employing a continuously burning pilot light, a third flue gas temperature measurement shall then be made to determine the off-period minimum flue gas temperature ($T_{F,\ OFF\ (\infty)}$). For units not employing a continuously burning pilot light, $T_{F,\ OFF\ (\infty)}$ is assumed to equal 70° F (21.1° C). During this cool down test, the energy input rate to the pilot light (Q_p), if the unit is so equipped, shall also be measured to within an accuracy of ±3 percent. Record all measured values. If a furnace with a direct vent system employs an automatic stack damper, it shall be closed during this cool down test.

3.2.3 Oil Fueled Forced Air Central Furnaces (including direct vent systems)

After steady-state testing has been completed, turn the main burner off and measure the flue gas temperature at 1.5 ($T_{F,\ OFF\ (t_2)}$) and 9.0 ($T_{F,\ OFF\ (t_4)}$) minutes after the burner shuts off using a single bead-type thermocouple, not larger than 24 AWG, located in the center of the flue pipe and the locations prescribed in section 2.6.5. During this off-period, the indoor air circulating blower shall be made to operate during the first 3 minutes of the off-period and then turned off unless the furnace employs a single motor to drive a power burner and an indoor air circulating blower, in which case both shall be turned off. The burner shall remain off until equilibrium conditions are attained, as indicated by temperature changes in the flue gas of not more than 3° F (2.8° C) between readings 15 minutes apart. For units employing a continuously burning pilot light, a third flue gas temperature measurement shall then be made to determine the off-period minimum flue gas temperature ($T_{F,\ OFF\ (\infty)}$). For units not employing a continuously burning pilot light, $T_{F,\ OFF\ (\infty)}$ is assumed to equal 70° F (21.1° C). During the cool down test, the energy input rate to the pilot light (Q_p), if the unit is so equipped, shall also be measured to within an accuracy of ±3 percent. Record all measured values. During the cool down test for furnaces not equipped with stack dampers, a means shall be provided to maintain the draft in the flue within ±0.01 inches of water gauge of the average value measured in the steady-state performance test. On units equipped with stack dampers, the damper shall be closed during this cool down test.

3.2.4 Gas and Oil Fueled Low Pressure Steam and Hot Water Boilers

After steady-state testing has been completed, turn the main burner off and measure the flue gas temperature at 3.75 ($T_{F,\ OFF\ (t_3)}$) and 22.5 ($T_{F,\ OFF\ (t_4)}$) minutes after the burner shuts off using a single bead-type thermocouple, not larger than 24 AWG, located in the center of the flue pipe and one inch (25.4 mm) from its outlet. During this off-period, no water shall be allowed to circulate through the hot water boiler. A third flue gas temperature measurement shall then be made 45 minutes after the burner shuts off to determine the off-period minimum flue gas temperature ($T_{F\ OFF\ (\infty)}$). During this cool-down test, the energy input rate to the pilot light (Q_p), if the unit is so equipped, shall be measured to within an accuracy of ±3 percent. Record all measured values. For oil fueled units not equipped with stack dampers, a means shall be provided to maintain the draft in the flue within ±0.01 inches of water gauge of the average value measured in the steady-state performance test.

3.3 *Flue Gas Temperature Measurement—Heat Up Test*

3.3.1 Gravity and Forced Air Central Furnaces (including direct vent systems)

After equilibrium conditions are achieved following the cool-down test and the required measurements performed, the furnace shall be turned on, the flue gas temperature measured at the same locations specified in section 3.2, at 0.5 ($T_{F,\ ON\ (t_1)}$) and 2.5 ($T_{F,\ ON\ (t_2)}$) minutes after the main burner(s) comes on. The indoor air circulating fan shall remain off during the first 1.5 minutes of this warm up test and shall then be turned on unless the furnace employs a single motor to drive a power burner and an indoor air circulating blower, in which case both shall be started together. Record the measured temperatures.

3.3.2 Low Pressure Steam and Hot Water Boilers

After equilibrium conditions are achieved following the cool-down test and the required measurements performed, the steam or hot water boiler shall be turned on and the flue gas temperature measured at the same locations specified in section 3.2 at 1.0 ($T_{F,\,ON(t_1)}$) and 5.5 ($T_{F,\,ON(t_2)}$) minutes after the main burner(s) comes on.

The pump circulating the water through the hot water boiler shall be started simultaneously with the main burner(s). During the heat-up test for oil fired boilers, means shall be provided to maintain the draft in the flue within ±0.01 inches of water column of the average draft measured in the steady-state test. Record the measured temperatures.

3.4 *Jacket Loss Measurement*

A jacket loss test is specified only for units intended to be installed outdoors. Measure the jacket loss (Lj) in accordance with the following ANSI standards and record the total loss and ambient room temperature during the test:

(i) Gravity central furnaces—Z21.47-1973, section 2.9.1 and Appendix F.

(ii) Gas fueled forced air central furnaces—Z21.47-1973, section 2.9.2 and Appendix F.

(iii) Gas fueled low pressure steam and hot water boiler—ANSI Z21.47-1973, section 2.9.2 and Appendix F.

(iv) Oil fueled forced air central furnaces—Z91.1-1972 Appendix B.

(v) Oil fueled low pressure steam and hot water boilers—ANSI Z21.47-1973, section 2.9.2 and Appendix F.

3.5 *Measurement for Determining Effectiveness of Stack Dampers*

The effectiveness of a stack damper (Do), in furnaces so equipped, shall be determined by measuring the cross sectional area of the stack (A_S), the net area of the damper plate (A_D) (the area of the damper plate minus the area of any holes in the plate), and the angle which is the angle the damper plate makes when closed with a plane perpendicular to the axis of the stack. The equation in section 4.3 is then employed to calculate Do.

3.6 *Measurements for Determining Dp for Systems Equipped with Power Burners*

On power burner systems not employing stack dampers or on power burner systems with a stack damper and an integral draft diverter, the flue gas temperature during the off-period ($T_{F,\,OFF}$) may be measured during the cool-down test described in section 3.2. The procedures to be used for measuring $T_{F,\,OFF}$ are described below.

On systems equipped with both power burners and stack dampers, and not employing an integral draft diverter, D_P shall be measured during a separate cool-down test. This separate cool-down test shall be conducted after warm-up test described in Section 3.3 for determining the on-period flue gas temperature. It shall be conducted by letting the unit run after the warm-up test is completed until steady-state conditions are reached, as indicated by temperature changes in the flue gas of not more than plus or minus 5° F (2.8° C) between readings 15 minutes apart, and then shutting the unit off with the stack damper controls by-passed or adjusted so that the stack damper remains open during the resulting cool-down period. If a draft was maintained in the flue during the steady state performance test described in Section 3.1 the same draft (within ±0.01 inches of water gauge of the average value measured during the steady-state tests) shall be maintained during this cool-down period.

The flue gas mass flow rate during the off-period ($\dot{m}_{F,OFF}$) may be measured at a specific off-period flue gas temperature and then corrected to obtain its value at a flue gas temperature at steady-state ($T_{F,SS}$), using the procedure described below.

Within one minute after the unit is shut off to start the cool down test for determining D_F, begin feeding a tracer gas into the combustion chamber at a constant flow rate, $\dot{V}_T$, and at a point which will allow for the best possible mixing with the air flowing through the chamber. On units equipped with an oil fired power burner, the best location for injecting this tracer gas is through a hole drilled in the blast tube. The value of $\dot{V}_T$ shall be periodically measured with an instantaneously reading flow meter having an accuracy of ±3 percent of the quantity measured and shall be less than 1 percent of the air flow rate through the furnace. If a combustible tracer gas is used, there should be a delay period between the time the unit is shut off and the time the tracer gas is first injected to prevent ignition of the tracer gas.

Between 5 and 6 minutes after the unit is shut off to start the cool-down test, the percent volumetric concentration of tracer gas, C_T, in the flue gas and the flue gas temperature, $T_{F,\,OFF}$, shall be measured in the center of the flue pipe on the furnace (boiler) side of the draft regulator and not more than 12 inches from the furnace flue-gas outlet. In addition, the barometric pressure shall also be determined. A single bead-type thermocouple, not larger than No. 24 AWG, shall be used to make the temperature measurement. The concentration of tracer gas shall be obtained using an instrument which will result in an accuracy of ±2 percent in the value of C_T measured and may be either a batch or continuous reading type instrument. If the sampling arrangement for the instrument results in a delay time between drawing of a sample and its analysis, this delay should be taken into account so that the temperature measurement and the measurement of tracer gas concentration coincide.

The rate of the flue gas mass flow through the furnace and the factors D_P, D_F, and D_S are calculated by the equations in section 4.4 of this Appendix.

4.0 Calculation of Derived Results From Test Measurements

4.1 *Annual Fuel Utilization Efficiency for Electric Furnaces and Boilers*

The annual fuel utilization efficiency for electric furnaces and boilers, $EFFY_{A-E}$, is given by:

$EFFY_{A-E}=100$ (for indoor units)

$EFFY_{A-E}=100-3.3\,L_j$ (for electric forced air central furnaces intended for outdoor installation)

$EFFY_{A-E}=100-4.7\,L_j$ (for electric boilers intended for outdoor installation)

where L_j=the jacket loss as determined in section 3.4 of this Appendix.

4.2 *Annual Fuel Utilization Efficiency for Gas or Oil Furnaces*

The following calculations are to be performed to determine the annual fuel utilization of a gas or oil furnace. Figure 10 provides an illustration of a worksheet which may be used to tabulate the results of test measurements and calculations.

4.2.1 System number

Determine the system number for the type of furnace being tested in accordance with Table 1 or 2.

4.2.2 Ratio of combustion air to stoichiometric air

Determine the ratio of combustion air to stoichimetric air, $R_{T,\,F}$, from Figure 1 for the test fuel, by using the value of dry flue gas CO_2 concentration $X_{CO_2,\,F}$, determined in accordance with sections 3.1 and 3.2 of this Appendix.

4.2.3 Ratio of combustion and relief air to stoichiometric air

For systems 1, 2, 5, or 6 employing an integral draft diverter, determine the ratio of the sum of combustion and relief air to stoichiometric air, $R_{T,\,S}$, from Figure 1 for the type of test fuel, by using the value of dry stack gas CO_2 concentration, $X_{CO_2,\,S}$, determined in accordance with section 3.1 of this Appendix.

4.2.4 Average sensible heat loss at full-load steady state operation

For systems, 1, 2, 5, or 6 employing an integral draft diverter, determine the average sensible heat loss at full-load steady-state operation, $L_{S,\,S,\,S,\,A}$, expressed as a percent, from Figure 2 using the value of $R_{T,\,S}$ determined in 4.2.4, the type of test fuel, and $\Delta T_{S,\,SS}$,

where

$$\Delta T_{S,\,SS}=T_{S,\,SS,\,X}-70,$$

where

$T_{S,\,SS,\,X}$=measured stack gas temperature at full-load steady-state operation determined in accordance with section 3.1 of this Appendix, in degrees Farenheit

70=assumed indoor average conditioned air temperature, in degrees Farenheit

For systems 3, 4, or 7 through 12, or systems 1, 2, 5, or 6 employing a draft hood, determine the average sensible heat loss a full-load steady-state operation, $L_{S,\,SS,\,A}$, expressed as a percent, from Figure 2 using the value of $R_{T,\,F}$ determined in 4.2.2, the type of test fuel, and $\Delta T_{F,\,SS}$,

where

$$\Delta T_{F,\,SS}=T_{F,\,SS}-70$$

where

$T_{F,\,SS}$=flue gas temperature at full-load steady-state operation determined in accordance with section 3.1 of this Appendix, in degrees Fahrenheit

70=as defined above

4.2.5 Steady state efficiency

Calculate the steady-state efficiency (excluding jacket loss), η_{SS}, expressed in percent and defined as

$$\eta_{SS}=100-L_{L,\,A}-L_{S,\,SS,\,A}$$

where

$L_{L,\,A}$=average latent heat loss of the test fuel determined in accordance with Table 3, in percent.

$L_{S,\,SS,\,A}$=as defined in 4.2.4

4.2.6 Average ratio of stack gas mass flow rate to flue gas mass flow rate at full-load steady-state operation

Determine the average ratio of stack gas mass flow rate to flue gas mass flow at full-load steady-state operation, $S/_F$, from Table 1 or 2 for the system number to be tested.

4.2.7 Equivalent field stack gas temperature at full-load steady-state operation

Calculate the equivalent field stack gas temperature at ull-load steady-state operation, $T_{S,\,SS}$, expressed in degrees Fahrenheit and defined as:

$$T_{S,\,SS}=\frac{1}{S/_F}\,[T_{F,\,SS}-70]+70,$$

where

$T_{F,\,SS}$ as defined in 4.2.4

70 as defined in 4.2.4

$S/_F$ as defined in 4.2.6

4.2.8 On-cycle time constant.

Calculate the on-cycle time constant, τ_{on}, expressed in minutes and defined as:

$$\tau_{on}=\frac{t_2-t_1}{\ln\left[\dfrac{T_{F,\,SS}-T_{F,\,on}(t_1)}{T_{F,\,SS}-T_{F,\,on}(t_2)}\right]}$$

where

for furnaces: t_1=0.5 minutes
t_2=2.5 minutes

for boilers: t_1=1.0 minutes
t_2=5.5 minutes

$T_{F,\,on}(t_1)$=flue gas temperature measured at time (t_1) from a cold start-up of the system burner determined in accordance with section 3.3 of this Appendix, in degrees Fahrenheit.

$T_{F,\,on}(t_2)$=flue gas temperature measured at the time (t_2) from a cold start-up of the system burner determined in accordance with section 3.3 of this Appendix, in degrees Fahrenheit as defined in 4.2.4.

$T_{F,\,SS}$

4.2.9 Effective flue gas temperature difference at start-up

Calculate the effective flue gas temperature difference at start-up of the system burner, $\theta_{F,O,X}$, expressed in degrees Fahrenheit and defined as:

$$\theta_{F,O,X}=[T_{F,SS}-T_{F,on}(t_1)]e^{\frac{t_1}{\tau_{on}}}$$

where

$T_{F,SS}$ as defined in 4.2.4

$T_{F,on}(t_1)$ as defined in 4.2.8

t_1 as defined in 4.2.8

τ_{on} as defined in 4.2.8

4.2.10 Off-cycle time constant

Calculate the off-cycle time constant, τ_{off}, expressed in minutes and defined as:

$$\tau_{off}=\frac{t_4-t_3}{\ln\left[\dfrac{T_{F,OFF}(t_3)-T_{F,OFF(\infty)}}{T_{F,OFF}(t_4)-T_{F,OFF(\infty)}}\right]}$$

where

for furnaces: t_3=1.5 minutes
t_4=9.0 minutes

for boilers: t_3=3.75 minutes
t_4=22.5 minutes

$T_{F,\,OFF}(t_3)$=flue gas temperature measured at time (t_3) after shut-down from steady-state operation of the system burner determined in accordance with section 3.2 of this Appendix, in degrees Fahrenheit.

$T_{F,\,OFF}(t_4)$=flue gas temperature measured at time (t_4) after shut-down from steady-state operation of the system burner determined in accordance with section 3.2 of this Appendix, in degrees Fahrenheit.

$T_{F,\,OFF}(\infty)$=minimum flue gas temperature determined in accordance with section 3.2 of this Appendix, in degrees Fahrenheit.

4.2.11 Effective flue gas temperature difference at shut-down

Calculate the effective flue gas temperature difference at shut-down of the system burner, $\psi_{F,\,O,\,X}$, expressed in degrees Fahrenheit and defined as:

$$\psi_{F,\,O,\,X}=[T_{F,\,OFF}(t_3)-T_{F,\,OFF}(\infty)]\,e^{\frac{t_3}{\tau_{off}}}$$

where

$T_{F,\,OFF}(t_3)$ as defined in 4.2.10

$T_{F,\,off}(\infty)$ as defined in 4.2.10

t_3 as defined in 4.2.10

τ_{off} as defined in 4.2.10

4.2.12 Minimum flue gas temperature difference above room temperature

Calculate the minimum flue gas temperature difference above room temperature, $\Psi_{F,\,\infty,\,X}$, expressed in degrees Fahrenheit and defined as:

$$\psi_{F,\,\infty,\,X}=T_{F,\,OFF}(\infty)-70,$$

where

$T_{F,\,OFF}(\infty)$ as defined in 4.2.10

70 as defined in 4.2.4

4.2.13 Minimum stack gas temperature difference above room temperature

Calculate the minimum stack gas temperature difference above room temperature, $\Psi_{S,\,\infty,\,X}$ expressed in degrees Fahrenheit and defined as:

For systems numbered 1-4:

$$\psi_{S,\,\infty\,X}=\frac{(D_F)\,(\psi_{F,\,\infty,\,X})}{(S/_F)\;(D_S)}$$

where
D_F=Off-cycle flue gas draft factor selected from Table 1 or, for units with power burners where D_F is measured, determined in accordance with section 4.4.2 of this Appendix, in degrees Fahrenheit.
D_S=Off-cycle stack gas draft factor selected from Table 1 or, for units with power burners where D_F is measured, determined in accordance with section 4.4.3 of this Appendix, in degrees Fahrenheit.
$S/_F$=as defined in 4.2.6
$\psi_{F,\infty,X}$=as defined in 4.2.12
for systems numbered 5-8:

$$\psi_{S,\infty,X}=\psi_{F,\infty,X}$$

where
$\psi_{F,\infty,X}$ as defined in 4.2.12

4.2.14 Effective stack gas temperature difference at shut-down.
Calculate the effective stack gas temperature difference at shut-down, $\psi_{S,O,X}$, expressed in degrees Fahrenheit and defined as:
for systems numbered 1-4:

$$\psi_{S,O,X}=\frac{(D_F)(\psi_{F,O,X})}{(S/_F)(D_S)}$$

where
D_F as defined in 4.2.13
$\psi_{F,O,X}$ as defined in 4.2.11
$S/_F$ as defined in 4.2.6
D_S as defined in 4.2.13
for systems numbered 5-8:

$$\psi_{F,O,X}=\psi_{F,O,X}$$

where
$\psi_{F,O,X}$ as defined in 4.2.11

4.2.15 Correction factors for direct vent systems
Calculate a correction factor which corrects for the use of outdoor air for combustion instead of air at room temperature, C_S, defined as

$$C_S=1+\frac{(70-42)\eta_{SS}}{(T_{F,SS}-70)}100$$

where
42 =average outdoor temperature corresponding to 5200 degree day location, in degrees Farenheit
η_{SS} as defined in 4.2.5
$T_{F,SS}$ as defined in 4.2.7
70 as defined in 4.2.4

The correction factor which corrects for the effect of outdoor air passing through the heat exchanger during the off-period, C'_S, is defined as:

$$C'_S=1.22$$

4.2.16 Multiplication factor for sensible heat loss during burner on-cycle
Calculate a multiplication factor for sensible heat loss during burner on-cycle, $K_{S,\,ON}$, defined

$$K_{S,\,ON}=\frac{100C_P[1+(R_{T,F})(A/_F)]}{HHV_A}$$

where
C_P=0.24 BTU per pound—degree Fahrenheit, specific heat of air
$R_{T,F}$ as defined in 4.2.2
$A/_F$=stoichiometric air/fuel ratio determined in accordance with Table 3
HHV_A average higher heating value of the test fuel determined in accordance with Table 3, in Btu's per pound.

4.2.17 Multiplication factor for sensible heat loss during burner off-cycle
Calculate a multiplication factor for sensible heat loss during burner off-cycle, $K_{S,\,OFF}$ defined as:
for system numbered 1-4:

$$K_{S,\,OFF}=\frac{(T_{F,SS}+460)^{1.19}(D_F)(K_{S,\,ON})}{(T_{F,SS}-70)^{0.56}}$$

Where
460=conversion factor to convert degrees Fahrenheit to degrees Rankine
$T_{F,SS}$ as defined in 4.2.4
70 as defined in 4.2.4
D_F as defined in 4.2.13
$K_{S,\,ON}$ as defined in 4.2.16
for systems numbered 5-8:

$$K_{S,\,OFF}=\frac{(T_{S,SS}+460)^{1.19}(D_S)(S/_F)(K_{S,\,ON})}{(T_{S,SS}-42)^{0.56}}$$

where
$T_{S,SS}$ as defined in 4.2.7
D_S as defined in 4.2.13
$S/_F$ as defined in 4.2.6
$K_{S,\,ON}$ as defined in 4.2.16
460 as defined in 4.2.17
42 as defined in 4.1.15
or systems numbered 9-12:

$$K_{S,\,OFF}=\frac{(T_{S,SS}+460)^{1.19}(D_F)(K_{S,\,ON})}{T_{S,SS}-42)^{0.56}}$$

where
$T_{S,SS}$ as defined in 4.2.7
D_F as defined in 4.2.13
$K_{S,\,ON}$ as defined in 4.2.16
460 as defined in 4.2.17
42 as defined in 4.2.15

4.2.18 Multiplication factor for infiltration loss during burner on-cycle
Calculate a multiplication factor for infiltration loss during burner on-cycle, $K_{I,\,ON}$, defined as: for systems numbered 1-8:

$$K_{I,\,ON}=(\phi)(S/_F)(K_{S,\,ON})$$

where
ϕ=0.7, infiltration parameter
$S/_F$ as defined in 4.2.6
$K_{S,\,ON}$ as defined in 4.2.16

4.2.19 Multiplication factor for infiltration loss during burner off-cycle
Calculate a multiplication factor for infiltration loss during burner off-cycle $K_{I,\,OFF}$, defined as: for systems numbered 1-8:

$$K_{I,\,OFF}=\frac{(T_{S,SS}+460)^{1.19}(K_{I,\,ON})(D_S)}{(T_{S,SS}-42)^{0.56}}$$

where
$T_{S,SS}$ as defined in 4.2.7
460 as defined in 4.2.17
42 as defined in 4.2.15
$K_{I,\,ON}$ as defined in 4.2.18
D_S as defined in 4.2.13

4.2.20 Ratio of average burner on-time per cycle to on-cycle time constant.
Calculate the ratio of average burner on-time per cycle to on-cycle time constant, t_{on}/τ_{on}, defined as:

$$\frac{t_{on}}{\tau_{on}}$$

where
for furnaces:
t_{on}=3.87 minutes, the average burner on-time per cycle, based on 5 cycles per hour at half load.
for boilers:
t_{on}=9.68 minutes, the average burner on-time per cycle, based on 2 cycles per hour at half load.
τ_{on} as defined in 4.2.8

4.2.21 Ratio of average burner off-time per cycle to off-cycle time constant
Calculate the ratio of average burner off-time per cycle to off-cycle time constant, t_{off}/τ_{off}, defined as:

$$\frac{t_{off}}{\tau_{off}}$$

where
for furnaces:
t_{off}=13.3 minutes, the average burner off-time per cycle, based on 5 cycles per hour at half load.
for boilers:
t_{off}=33.26 minutes, the average burner off-time per cycle, based on 2 cycles per hour at half load.
τ_{off}=as defined in 4.2.10

4.2.22 Effective flue gas temperature difference at burner start-up, corrected for burner cycling effect
Calculate the effective flue gas temperature difference at burner start-up, corrected for burner cycling effect, $\theta_{F,O}$ expressed in degrees Fahrenheit and defined as:
when

$$(t_{on}/\tau_{on})\leq(t_{off}/\tau_{off})$$

for systems numbered 1-8:

$$\theta_{F,O}=\theta_{F,O,X}$$

for systems numbered 9-12:

$$\theta_{F,O}=(C_S)(\theta_{F,O,X})$$

when

$$(t_{on}\tau_{on})>(t_{off}/\tau_{off});$$

for systems numbered 1-8:

$$\theta_{F,O}=\theta_{F,O,X}\left(1-e^{-\frac{t_{off}}{\tau_{off}}}\right)$$

for systems numbered 9-12:

$$\theta_{F,O}=(C_S)(\theta_{F,O,X})\left(1-e^{-\frac{t_{off}}{\tau_{off}}}\right)$$

where
t_{on}/τ_{on} as defined in 4.2.20
t_{off}/τ_{off} as defined in 4.2.21
$\theta_{F,O,X}$ as defined in 4.2.9
C_S as defined in 4.2.15

4.2.23 Effective flue gas temperature difference at burner shut-down, corrected for burner cycling effect
Calculate the effective flue gas temperature difference at burner shut-down, corrected for burner cycling effect, $\psi_{F,O}$, when

$$(t_{on}/\tau_{on})\leq(t_{off}/\tau_{off}):$$

for systems numbered 1-8:

$$\psi_{F,O}=(\psi_{F,O,X})\left(1-e^{-\frac{t_{on}}{\tau_{on}}}\right)$$

for systems numbered 9-12:

$$\psi_{F,O}=(C_S')(\psi_{F,O,X})\left(1-e^{-\frac{t_{on}}{\tau_{on}}}\right)$$

when

$$(t_{on}/\tau_{on})(t_{off}/\tau_{off})$$

for systems numbered 1-8:

$$\psi_{F,O}=\psi_{F,O,X}$$

for systems numbered 9-12:

$$\psi_{F,O}=\psi(C_S')_{(F,O,X)}$$

where
t_{on}/τ_{on} as defined in 4.2.20
t_{off}/τ_{off} as defined in 4.2.21
$\psi_{F,O,X}$ as defined in 4.2.11
C_S' as defined in 4.2.15

4.2.24 Effective minimum flue gas temperature difference above room temperature, corrected for burner cycling effect
Calculate the effective minimum flue gas temperature difference above room temperature, $\psi_{F,\infty}$, corrected for burner cycling effect, expressed in degrees Fahrenheit and defined as:
for systems numbered 1-8:

$$\psi_{F,\infty}=\psi_{F,\infty O,X_1}$$

for systems numbered 9-12:
where

$$\psi_{F,\infty}=(C_S)(\psi_{F,\infty,X})$$

C_S' as defined in 4.2.15
$\psi_{F,\infty,X}$ as defined in 4.2.12

4.2.25 Effective stack gas temperature difference at burner shut-down, corrected for burner cycling effect
Calculate the effective stack gas temperature difference at burner shut-down, corrected for burner cycling effect, $\psi_{S,O}$, expressed in degrees Fahrenheit and defined as:

when

$$(t_{on}/\tau_{on})\leq(t_{off}/\tau_{off})$$

for systems numbered 1-8:

$$\psi_{S,O}=\psi_{S,O,X}\left(1-e^{-\frac{t_{on}}{\tau_{on}}}\right)$$

when

$$t_{on}/\tau_{on}>(t_{off}/\tau_{off})$$

for systems numbered 1-8:

$$\psi_{S,O}=\psi_{S,O,X}$$

Where
t_{on}/τ_{on} as defined in 4.2.20
t_{off}/τ_{off} as defined in 4.2.21
$\psi_{S,O,X}$ as defined in 4.2.14

4.2.26 Off-cycle sensible heat loss integration factors
For systems numbered 1-4, determine off-cycle sensible heat loss integration factors, F3 and F4, from Figures 3 and 4, respectively, using values of $\psi_{F,O}$ defined in section 4.2.23, and t_{off}/τ_{off} defined in section 4.2.21.

For systtms numbered 5-12, determine off-cycle sensible heat loss integration factors, F5 and F6, from Figures 5 and 6, respectively, using values of $\psi_{F,O}$ defined in section 4.2.23, and t_{off}/τ_{off} defined in section 4.2.21.

4.2.27 Off-cycle infiltration heat loss integration factors
For systems numbered 1-8, determine off-cycle infiltration heat loss integration factors, F7 and F8, from Figures 7 and 8, respectively, using values of $\psi_{S,O}$ defined in section 4.2.26, and t_{off}/τ_{off} defined in section 4.2.21.

4.2.28 On-cycle sensible heat loss
Calculate the on-cycle sensible heat loss of the system, $L_{S,\,ON}$, expressed in percent and defined:

for systems numbered 1-8:

$$L_{S,\,ON}=L_{S,SS}-(K_{S,\,ON})(\theta_{F,O})\left(\frac{1}{t_{on}/\tau_{on}}\right)\left(1-e^{\left(-\frac{t_{on}}{\tau_{on}}\right)}\right),$$

for systems numbered 9-12:

$$L_{S,\,ON}=(C_S)(L_{S,SS,A})-(K_{S,\,ON})(\theta_{F,O})\left(\frac{1}{t_{on}/\tau_{on}}\right)\left(1-e^{\left(-\frac{t_{on}}{\tau_{on}}\right)}\right)$$

where
C_S as defined in 4.2.15
$L_{S,SS,A}$ as defined in 4.2.4
$K_{S,ON}$ as defined in 4.2.16
$\theta_{P,O}$ as defined in 4.2.22
t_{on}/τ_{on} as defined in 4.2.20

4.2.29 Off-cycle sensible heat loss

Calculate the off-cycle sensible heat loss of the system, $L_{S,OFF}$ expressed in percent and defined as:
for systems numbered 1-4:

$$L_{S,OFF}=(K_{S,OFF})\left(\frac{t_{off}}{t_{on}}\right)(F3)+(\psi_{F,\infty})(F4),$$

for systems numbered 5-12:

$$L_{S,OFF}=(K_{S,OFF})\left(\frac{t_{off}}{t_{on}}\right)(F5)+(\psi_{F,\infty})(F6),$$

where
$K_{S,OFF}$ as defined in 4.2.17
t_{off} as defined in 4.2.21
t_{on} as defined in 4.2.20
$F3$, $F4$, $F5$, and $F6$ as defined in 4.2.26
$\psi_{F,\infty}$ as defined in 4.2.24

4.2.30 On-cycle infiltration heat loss

Calculate the on-cycle infiltration heat loss of the system, $L_{I,ON}$, expressed in percent and defined as:
for systems numbered 1-8:

$$L_{I,ON}=K_{I,ON}(70-42),$$

where
$K_{I,ON}$ as defined in 4.2.18
70 as defined in 4.2.4
42 as defined in 4.2.15

for systems numbered 9-12:

$$L_{I,ON}=0$$

4.2.31 Off-cycle infiltration heat loss

Calculate the off-cycle infiltration heat loss of the system $L_{I,OFF}$, expressed in percent and defined as:
for systems number 1-8:

$$L_{I,OFF}=K_{I\ OFF}(70-42)\left(\frac{t_{off}}{t_{on}}\right)(F7)+(\psi_{S,\infty\ X})(F8)$$

where

$K_{I,OFF}$ as defined in 4.2.19
70 as defined in 4.2.4
42 as defined in 4.2.15
t_{off} as defined in 4.2.21
t_{on} as defined in 4.2.20
$F7$, $F8$ as defined in 4.2.27
$\psi_{S,\infty,X}$ as defined in 4.2.13

for systems numbered 9-12:

$$L_{I,OFF}=0$$

4.2.32 Part-load fuel utilization efficiency

Calculate the part-load fuel utilization efficiency, expressed in percent and defined as:

for indoor units:

$$\eta_u=100-L_{L,A}-\left[\frac{t_{on}}{t_{on}+\frac{Q_P}{Q_{in}}(t_{off})}\right][L_{S,ON}+L_{S,OFF}+L_{I,ON}+L_{I,OFF}]$$

for outdoor units:

$$\eta_u=100-L_{L,A}-C_i(L_i)-\left[\frac{t_{on}}{t_{on}+\frac{(Q_P)}{Q_{in}}(t_{off})}\right][L_{S,ON}+L_{S,OFF}+L_{I,ON}+L_{I,OFF}]$$

where
C_i=3.3 for furnaces intended to be installed outdoors
4.7 for boilers intended to be installed outdoors
Q_P=pilot flame fuel input rate determined in accordance with section 3.2 of this Appendix, in Btu's per hour
Q_{IN}=full-load input rate (including pilot flame fuel input rate) determined in accordance with section 3.1 of this Appendix, in Btu's per hour
L_i=jacket loss determined in accordance with section 3.4 of this Appendix, in percent
$L_{L,A}$ as defined in 4.2.5
t_{ON} as defined in 4.2.20
t_{OFF} as defined in 4.2.21
$L_{S,ON}$ as defined in 4.2.28
$L_{S,OFF}$ as defined in 4.2.29
$L_{I,ON}$ as defined in 4.2.30
$L_{I,OFF}$ as defined in 4.2.31

4.2.33 Annual fuel utilization efficiency

Calculate the annual fuel utilization efficiency, $EFFYA$ defined as:

$$EFFY_A=\frac{(\eta_{SS})(\eta_u)(5200)}{(\eta_{SS})(5200)+(2.5)(\eta_u)\left(\frac{Q_P}{Q_{in}}\right)(1.7)(4600)}$$

where
5200=the average number of annual heating degree days for the United States
4600=the average number of non heating season hours per year that the energy to the pilot light is assumed wasted
1.7=average furnace sizing factor
η_{SS}=as defined in 4.2.5
η_u=as defined in 4.2.32
Q_P=as defined in 4.2.32
Q_{IN}=as defined in 4.2.32

4.3 *Additional Requirements for Furnaces Utilizing a Stack (or flue) Damper.*

Calculate the automatic stack (or flue) damper effectiveness, D_O, defined as:
when

$$A_D\cos\Phi>0.59\ A_S:$$

$$D_O=\frac{2.24\left[1-\frac{A_D\cos\Phi}{A_S}\right]}{\sqrt{1-\left[1-\frac{A_D\cos\Phi}{A_S}\right]^2}}$$

when

$$A_D\cos\Phi\leq 0.59\ A_S:$$

$$D_O=1,$$

where
A_S=cross sectional area of the stack determined in accordance with section 3.5 of this appendix, in square inches
A_D=net area of the damper plate determined in accordance with section 3.5 of this appendix, in square inches
Φ=the angle the damper plate makes when closed with a plane perpendicular to the axis of the stack

4.4 *Additional Requirements for Furnaces Utilizing Indoor Air for Combustion and Draft Control.*

For units obtaining combustion air and draft control air from inside the residence, the appropriate factor describing the ratio of on-cycle stack flow to on-cycle flue flow (S/F), the ratio of off-cycle flue flow to on-cycle flow at identical temperatures (D_F), and the ratio of off-cycle stack flow to on-cycle stack flow at identical temperatures (D_S) shall be determined from Table 1.

4.4.1 Optional procedure for determination of D_F for furnaces or boilers employing a power burner

Calculate the ratio (D_F) of the rate of flue gas mass flow through the furnace or boiler during the off period, $\dot{m}_{F,\ OFF}\ (T_{F,\ SS})$, to the rate of flue gas mass flow during the on-period, $\dot{m}_{F,\ SS}\ (T_{F,\ SS})$, and defined as:

$$D_P=\frac{\dot{m}_{F,\ OFF}(T_{F,SS})}{\dot{m}_{F,\ SS}(T_{F,\ SS})}$$

where

$$\dot{m}_{F,\ OFF}(T_{F,SS})=\dot{m}_{F,\ OFF}(T_{F,\ OFF})\cdot\left[\frac{T_{F,SS}-42}{T_{F,\ OFF}-42}\right]^{0.58}\left[\frac{T_{F,\ OFF}+460}{T_{F,SS}+460}\right]^{1.19}$$

where
$T_{F,\ SS}$ =as defined in 4.2.4
$T_{F,\ OFF}$=flue gas temperature during the off-period measured in accordance with section 3.6 of this Appendix, in degrees Fahrenheit

$$\dot{m}_{F,\ OFF}(T_{F,\ OFF})=\frac{100\dot{V}_T}{C_T}\rho_F,$$

where
$\dot{V}_T$=flow rate of tracer gas through the furnace measured in accordance with section 3.6 of this Appendix, in cubic feet per minute
C_T=concentration by volume of tracer gas present in the flue gas sample measured in accordance with section 3.6 of this Appendix, in percent

$$\rho_F=\frac{1.325P_B}{460+T_{F,\ OFF}},$$

where
$T_{F,OFF}$ as defined above
P_B =barometric pressure measured in accordance with section 3.6 of this Appendix, in inches of mercury

$$\dot{m}_{F,SS}(T_{F,SS})=\left[(R_{T,F})\left(\frac{A}{F}\right)+\ \right]\frac{Q_{in}}{HHV_A},$$

where
$R_{T,F}$ as defined in 4.2.2
A/F as defined in 4.2.16
Q_{in} as defined 4.2.32
HHV_A as defined in 4.2.16

4.4.2 Optional procedure for determination of off-cycle draft factor for flue gas flow for furnaces or boilers employing a power burner

Calculate the off-cycle draft factor for flue gas flow, D_F, defined as
for systems numbered 2, 4 or 10: $D_F=D_P$,
for system number 12: $D_F=(D_P)(D_O)$,
where
D_P as defined in 4.4.1
D_O as defined in 4.3

4.4.3 Optional procedure for determination of off-cycle draft factor for stack gas flow for furnaces or boilers employing a power burner

Calculate the off-cycle draft factor for stack gas flow, D_S, defined as:
for system number 2: $D_S=D_P+0.55$
for system number 4: $D_S=D_P+.40$;
for system number 8: $D_S=(D_P)\ (D_O)$,
where
D_P as defined in 4.4.1
D_O as defined in 4.3

4.5 *Additional Requirements for Furnaces Utilizing a Direct Vent System*

For furnaces utilizing a direct vent system or intended for outdoor installation, the appropriate S/F factor and D_F factor shall be determined from Table 2. If a unit is equipped with a power burner, D_F may be calculated using the value of D_P determined in section 4.4.1 of this section.

4.6 *Additional Requirements for Furnaces Which Modulate or Vary Fuel Input Without Controlling Excess Combustion Air*

A furnace which is equipped with a mechanism for reducing the rate of fuel input but does not provide a means for controlling excess combustion air, shall be tested at its maximum firing rate in accordance with test procedures in section 3. These test results shall be used to calculate a seasonal efficiency and an annual operating cost which is based upon a single fixed fuel input rate.

4.7 *National Average Number of Burner Operating Hours*

Calculate the average number of burner operating hours, BOH, defined as

$$BOH=(A)\ (2080)\ (\text{design heating requirement})-B,$$

where
2080=national average annual heating load hours

$$\text{design heating requirement}=\frac{(Q_{in})\ (0.5)}{1000}$$

where
0.5= approximate value for the ratio of steady state efficiency to 100 times the average furnace sizing factor
1000= conversion factor to convert Btu's per hour to kilo-Btu's per hour
Q_{IN} as defined in 4.2.32

$$A=\frac{100{,}000}{(341{,}300)\ (PE+y\ BE)+(Q_{in}-Q_P)\ \eta_u}$$

$$B=(0.0416)\ (Q_P)\ (\eta_u)\ (A)$$

PE= power burner electrical energy input rate at full-load steady-state operation determined in accordance with section 3.1 of this Appendix, in kilowatts.
BE= Circulating-air blower (or circulating-water pump) electrical energy input rate at full-load steady-state operation determined in accordance with section 3.1 of this Appendix, in kilowatts
y= 1.38 for furnaces
1.00 for boilers or furnaces employing a single motor to drive a power burner and air circulating fan or blower, the ratio of average blower or pump on time to average burner on time
Q_{IN} as defined in 4.2.32
Q_P as defined in 4.2.32
η_u as defined in 4.2.32

4.8 *Average Annual Fuel Energy Consumption for Gas or Oil Fueled Furnaces or Boilers*

Calculate the average annual fuel energy consumption for gas or oil fueled furnaces or boilers, E_F, expressed in Btu's per year, and defined as:

$$E_F=Q_{IN}-(Q_P)(BOH)+(8760)(Q_P),$$

where
Q_{IN} as defined in 4.2.32
Q_P as defined in 4.2.32
BOH as defined in 4.7
8760=total number of hours in a year

4.9 *Average Annual Auxiliary Electrical Energy Consumption for Gas or Oil Fueled Furnaces or Boilers*

Calculate the average annual auxiliary electrical energy consumption, E_{AE}, expressed in kilowatt-hours per year and defined as:
where
$E_{AE}=(PE+yBe)(BOH)$
PE as defined in 4.7
BE as defined in 4.7
y as defined in 4.7
BOH as defined in 4.7

4.10 *Average Annual Electric Energy Consumption for Electric Furnaces or Boilers*

Calculate the average annual electric energy consumption for electric furnaces or boilers, E_E, expressed in kilowatt-hours per year, and defined as:

$$E_E = \frac{(100)(2080)(\text{design heating requirement})}{EFFY_{A-E}} E_I$$

where
100 = conversion factor to convert percent to decimal fraction

$$(\text{design heating requirement}) = \frac{(E_{ni})(0.5)}{E\ 1000}$$

where
E_{in} = electric power input measured in accordance with section 3.1.7 of this Appendix
0.5 as defined in 4.7
1000 as defined in 4.7
2080 as defined in 4.7
$EFFY_{A-E}$ as defined in 4.1

4.11 *Average Number of Burner Operating Hours in Different Geographic Regions of the United States*

Calculate the average number of burner operating hours by geographic region of the United States, BOH_R, defined as:

$$BOH_R = (HLH)\ (\text{design heating requirement}) - B,$$

where
HLH = heating load hours for a specific geographic region determined in accordance with the heating load hour map in Figure 9

$$B = \frac{(2)(HLH)(A)(Q_P)(\eta_{SO})}{100{,}000}$$

where
HLH as defined above
A as defined in 4.7
Q_P as defined in 4.2.32
η_{so} as defined in 4.2.32

Design heating requirement as defined in 4.7

$$E_{E,\ R} = \frac{(100)\ (HLH)\ (\text{design heating requirement})}{(EFFY_{A-E})} E$$

where
100 as defined in 4.10
HLH as defined in 4.11
(design heating requirement)$_E$ as defined in 4.10
$EFFY_{A-E}$ as defined in 4.1

4.15 *Minimum Standardized Design Heating Requirement*

Calculate the minimum standardized design heating requirement, DHR_{MIN}, expressed in Btu's per-hour for which a regional annual operating cost could be computed, defined as:

$$DHR_{MIN} = \frac{(\eta_{so})\ (Q_{in})}{200}$$

4.16 *Maximum Standardized Design Heating Requirement*

Calculate the maximum standardized design heating requirement, DHR_{MAX}, expressed in Btu's per-hour, for which a regional annual operating cost could be computed, defined as:

$$DHR_{MAX} = \frac{(\eta_{so})\ (Q_{in})}{110}$$

4.17 *Average Number of Burner Operating Hours by Geographic Region of the United States for the Minimum Standardized Design Heating Requirement*

Calculate the average number of burner operating hours by geographic region of the United State for the minimum standardized design heating requirement, BOH_{R-MIN}, defined as:

$$BOH_{R-MIN} = A(HLH)\ (DHR_{MIN}) - B,$$

where
A as defined in 4.7
HLH as defined in 4.11
DHR_{MIN} as defined in 4.15
B as defined in 4.7

4.12 *Average Annual Fuel Energy Consumption for Gas or Oil Fueled Furnaces or Boilers by Geographic Region of the United States*

Calculate the average annual fuel energy consumption by geographic region of the United States, $E_{F,R}$, expressed in Btu's per year, and defined as:

$$E_{F,\ R} = (Q_{IN} - Q_P)\ (BOH_R) + (8760)\ (Q_P),$$

where
Q_{in} as defined in 4.2.32
Q_P as defined in 4.2.32
BOH_R as defined in 4.11
8760 as defined in 4.8

4.13 *Average Annual Auxiliary Electrical Energy Consumption for Gas or Oil Fueled Furnaces or Boilers by Geographic Region of the United States*

Calculate the average annual auxiliary electrical energy consumption by geographic regions of the United States, $E_{AE,R}$ expressed in kilowatt-hours per year and defined as:

$$E_{AE,\ R} = (PE + y\ BE)\ (BOH_R),$$

where
PE as defined in 4.7
BE as defined in 4.7
Y as defined in 4.7
BOH_R as defined in 4.11

4.14 *Average Annual Electric Energy Consumption for Electric Furnaces or Boilers by Geographic Region of the United States*

Calculate the average annual electric energy consumption by geographic region of the United States, $E_{E,R}$, expressed in kilowatt-hours per year, and defined as:

$$E_{E,\ R} = \frac{(100)\ (HLH)\ (\text{design heating requirement})}{(EFFY_{A-E})} E$$

where
100 as defined in 4.10
HLH as defined in 4.11
(design heating requirement)$_E$ as defined in 4.10
$EFFY_{A-E}$ as defined in 4.1

4.15 *Minimum Standardized Design Heating Requirement*

Calculate the minimum standardized design heating requirement, DHR_{MIN}, expressed in Btu's per-hour for which a regional annual operating cost could be computed, defined as:

$$DHR_{MIN} = \frac{(\eta_{so})\ (Q_{in})}{200}$$

4.16 *Maximum Standardized Design Heating Requirement*

Calculate the maximum standardized design heating requirement, DHR_{MAX}, expressed in Btu's per-hour, for which a regional annual operating cost could be computed, defined as:

$$DHR_{MAX} = \frac{(\eta_{so})\ (Q_{in})}{110}$$

4.17 *Average Number of Burner Operating Hours by Geographic Region of the United States for the Minimum Standardized Design Heating Requirement*

Calculate the average number of burner operating hours by geographic region of the United State for the minimum standardized design heating requirement, BOH_{R-MIN}, defined as:

$$BOH_{R-MIN} = A(HLH)\ (DHR_{MIN}) - B,$$

where
A as defined in 4.7
HLH as defined in 4.11
DHR_{MIN} as defined in 4.15
B as defined in 4.7

4.18 *Maximum Standardized Design Heating Requirement*

Calculate the maximum standardized design heating requirement, DHR_{MAX}, expressed in Btu's per-hour, for which a regional annual operating cost could be computed, defined as:

$$DHR_{MAX} = \frac{(\eta_{so})\ (Q_{in})}{110}$$

4.19 *Average Annual Fuel Energy Consumption for Gas or Oil Furnaces or Boilers by Geographic Region of the United States for the Minimum Standardized Design Heating Requirement*

Calculate the average annual fuel energy consumption by geographic region of the United States for the minimum design heating requirement, $E_{F,R-MIN}$, expressed in Btu's per year and defined as:

$$E_{F,\ R-MIN} = (Q_{in} - Q_P)\ (BOH_{R-MIN}) + (8760)\ (Q_P),$$

where
Q_{in} as defined in 4.2.32
Q_P as defined in 4.2.32
BOH_{R-MIN} as defined in 4.17
as defined in 4.8

4.20 *Average Annual Fuel Energy Consumption for Gas or Oil Furnaces or Boilers by Geographic Region of the United States for the Maximum Standardized Design Heating Requirement*

Calculate the average annual fuel energy consumption by geographic region of the United States for the maximum design heating requirement, $E_{F,R-MAX}$, expressed in Btu's per year and defined as:

$$E_{F,\ R-MAX} = (Q_{IN} - Q_P)\ (BOH_{R-MAX}) + (8760)\ (Q_P),$$

where
Q_{IN} as defined in 4.2.32
Q_P as defined in 4.2.32
BOH_{R-MAX} as defined in 4.17
8760 as defined in 4.8

4.21 *Average Annual Auxiliary Electrical Energy Consumption for Gas or Oil Fueled Furnaces or Boilers by Geographic Region of the United States for the Minimum Standardized Design Heating Requirement*

Calculate the average annual auxiliary electrical energy consumption by geographic region of the United States for the minimum design heating, requirement $E_{AE,R-MIN}$, expressed in kilowatt-hours per year and defined as:

$$E_{AE,\ R-MIN} = (PE + y\ BE)\ (BOH_{R-MIN}),$$

where
PE as defined in 4.7
y as defined in 4.7
BE as defined in 4.7
BOH_{R-MIN} as defined in 4.11

4.22 *Average Annual Auxiliary Electrical Energy Consumption for Gas or Oil Fueled Furnaces or Boilers by Geographic Region of the United States for the Maximum Standardized Design Heating Requirement*

Calculate the average annual auxiliary electrical energy consumption by geographic region of the United States for the maximum design heating requirement,

$$E_{AE,\ R-MAX} = (PE + yBE)\ (BOH_{R-MAX}),$$

where
PE as defined in 4.6
Y as defined in 4.7
BE as defined in 4.7
BOH_{R-MAX} as defined in 4.11

4.23 *Average Annual Electric Energy Consumption for Electric Furnaces or Boilers by Geographic Region of the United States for the Minimum Standardized Design Heating Requirement*

Calculate the average annual electric energy consumption by geographic region of the United States for the minimum design heating requirement, $E_{E,R\ MIN}$ expressed in kilowatt-hours per year and defined as:

$$E_{E,\ R-MIN} = \frac{(100)\ (HLH)\ (DHR_{MIN})}{(EFFY_{A-E})}$$

where
100 as defined in 4.10
HLH as defined in 4.11
DHR_{MIN} as defined in 4.15
$EFFY_{A-E}$ as defined in 4.1

4.24 *Average Annual Electric Energy Consumption for Electric Furnaces or Boilers by Geographic Region of the United States for the Maximum Standardized Design Heating Requirement*

Calculate the average annual electric energy consumption by geographic region of the United States for the maximum design heating requirement, $E_{E,R-MAX}$ expressed in kilowatt-hours per year and defined as:

$$E_{E,R-MAX} = \frac{(100)(HLH)(DHR_{MAX}),}{(EFFY_{A-E})}$$

where
100 as defined in 4.10
HLH as defined in 4.11
DHR_{MAX} as defined in 4.16
$EFFY_{A-E}$ as defined in 4.1

Table 1

Factors Describing Air Flow Rate for Gas and Oil-Fired Furnaces or Boilers Utilizing Indoor Air for Combustion and Draft Control

Type of Burner	Units Without a Stack Damper but with Draft Hood or Draft Diverter				Barometric Draft Control				Units With a Stack Damper and Draft Hood or Draft Diverter				Barometric Draft Control			
	System #	S/F	D_F	D_S	System #	S/F	D_F	D_S	System #	S/F	D_F	D_S	System #	S/F	D_F	D_S
Atmospheric	1	2.4	1.0	1.0	3	1.4	1.0	1.0	5	2.4	---	D_o	7	1.4	---	D_o
Power	2	2.4	0.3	0.85	4	1.4	.10	0.70	6	2.4	---	D_o	8	1.4	--	$0.10 \times D_o$

The above factors were developed by the National Bureau of Standards and are based upon information in the public literature, laboratory and computer simulation studies conducted at NBS, and laboratory and field data obtained by several research firms under contract to NBS and FEA.

Table 2

Factors Describing Air Flow Rates for Gas or Oil-Fired Furnaces/Boilers Intended for Installation Out-Of-Doors or Intended for Indoor Installation But Equipped With a direct vent system.

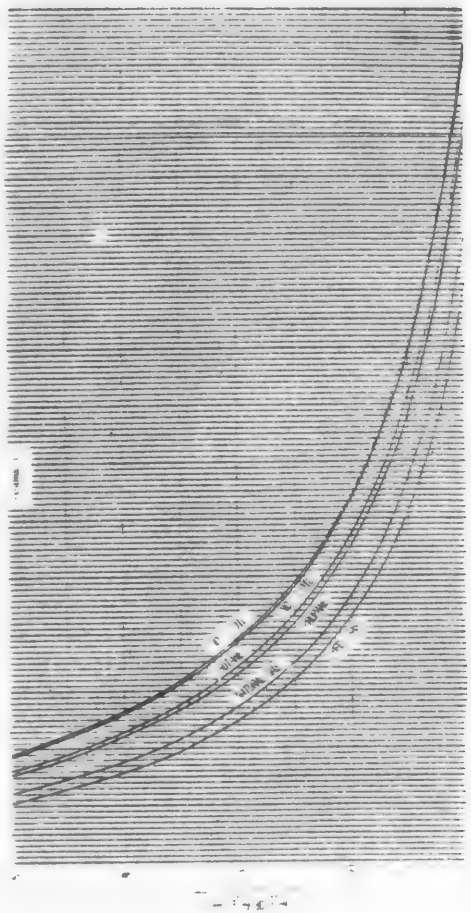
Type of Burner	Units Without A Stack Or Flue Damper		Outdoor Units With a Flue Damper Or Indoor Units With a Stack Damper		Type of Draft	S/F
	System #	D_F	System #	D_F	None	1
Atmosphere	9	1.00	11	D_o	barometric damper	1.4
Power	10	0.30	12	$0.30 \times D_o$	draft diverter	2.4

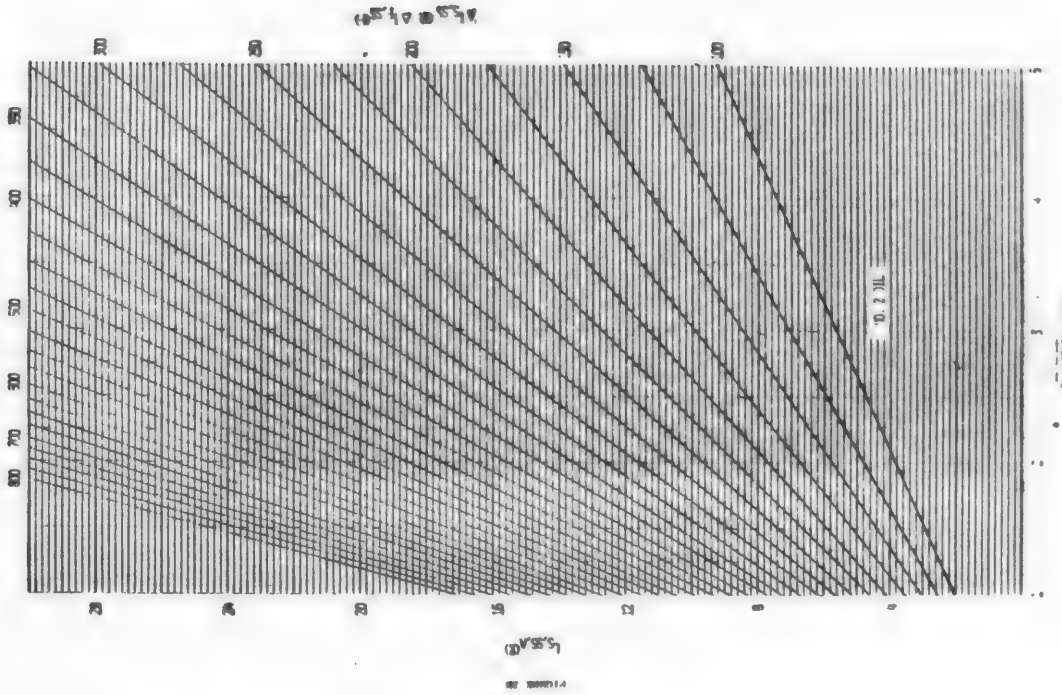
The above factors were developed by the National Bureau of Standards and are based upon information in the public literature, laboratory and computer simulation studies conducted at NBS, and laboratory and field data obtained by several research firms under contract to NBS and FEA.

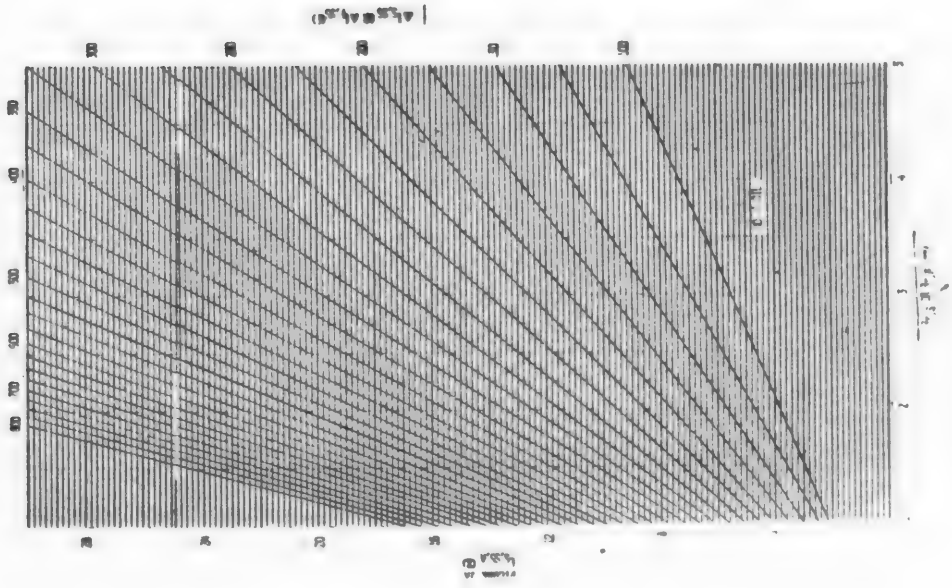
Table 3

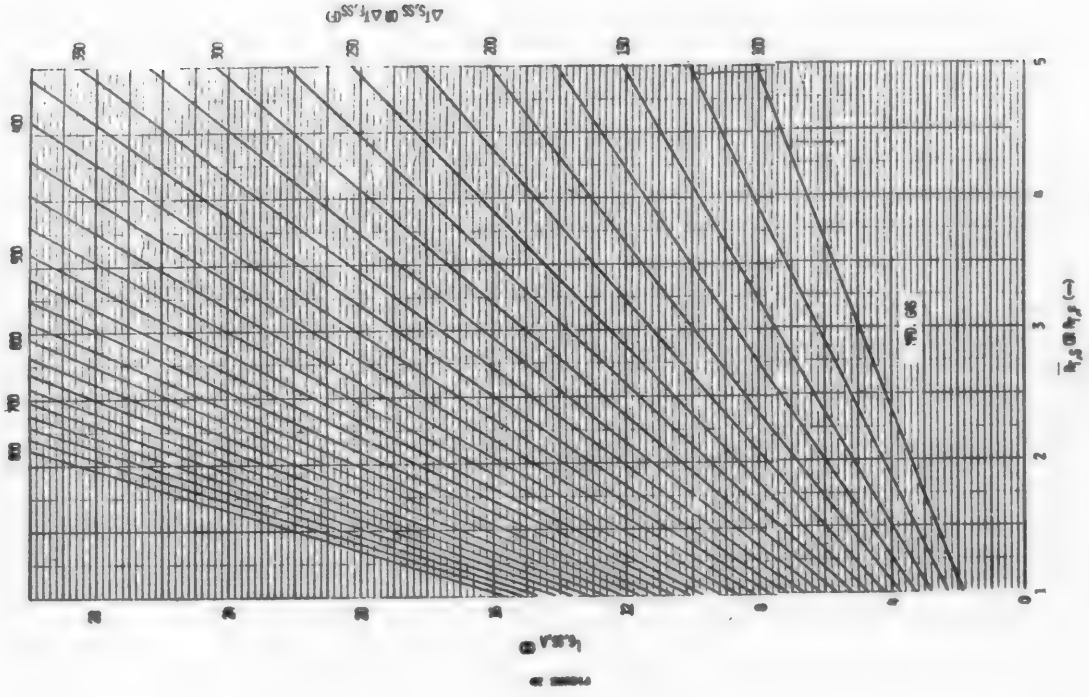
Values of Higher Heating Value (HHV_A), Stoichiometric Air/Fuel Ratio (A/F), and Latent Heat Loss ($L_{L,A}$) for Typical Fuels

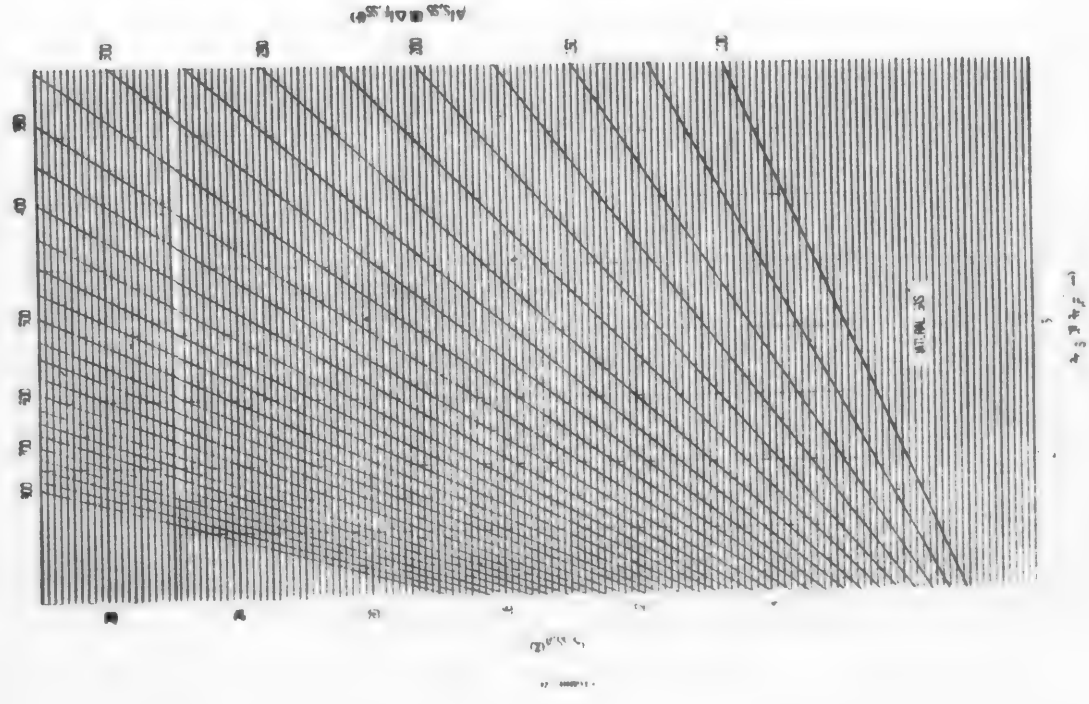
Fuels	HHV_A (Btu/lb)	A/F(—)	$L_{L,A}$(%)
No.1 Oil	19,800	14.58	6.55
No.2 Oil	19,500	14.51	6.50
Natural Gas	21,800	16.04	9.91
Manufactured Gas	18,500	11.83	10.16
Propane	21,500	15.60	8.00
Butane	20,890	15.38	7.80

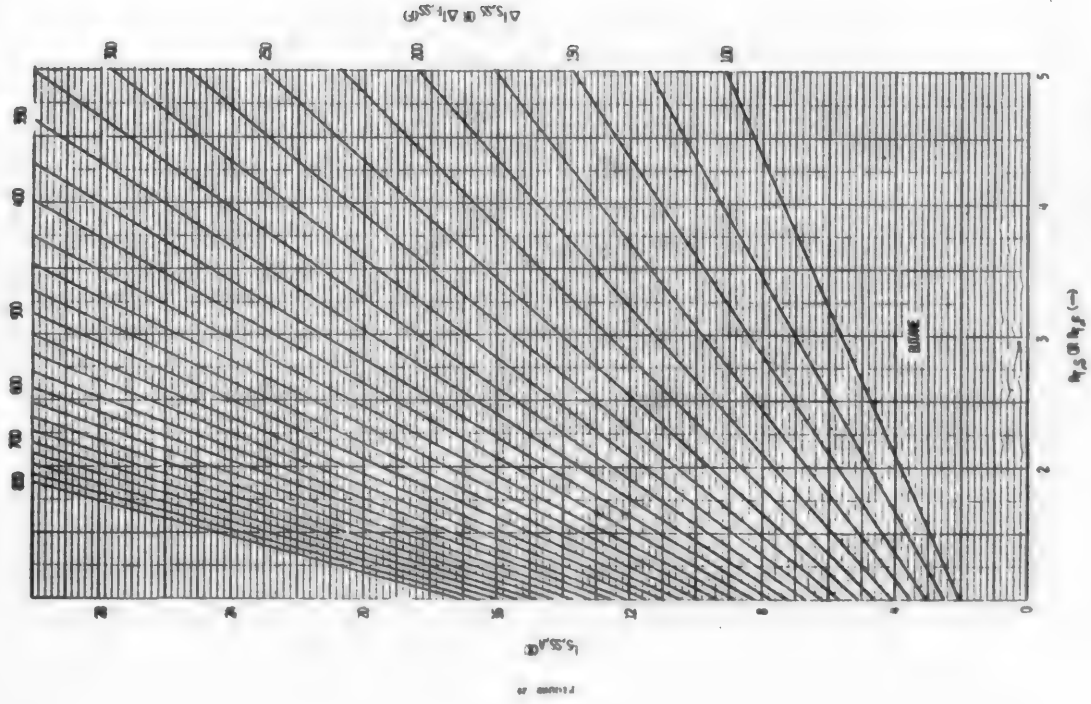












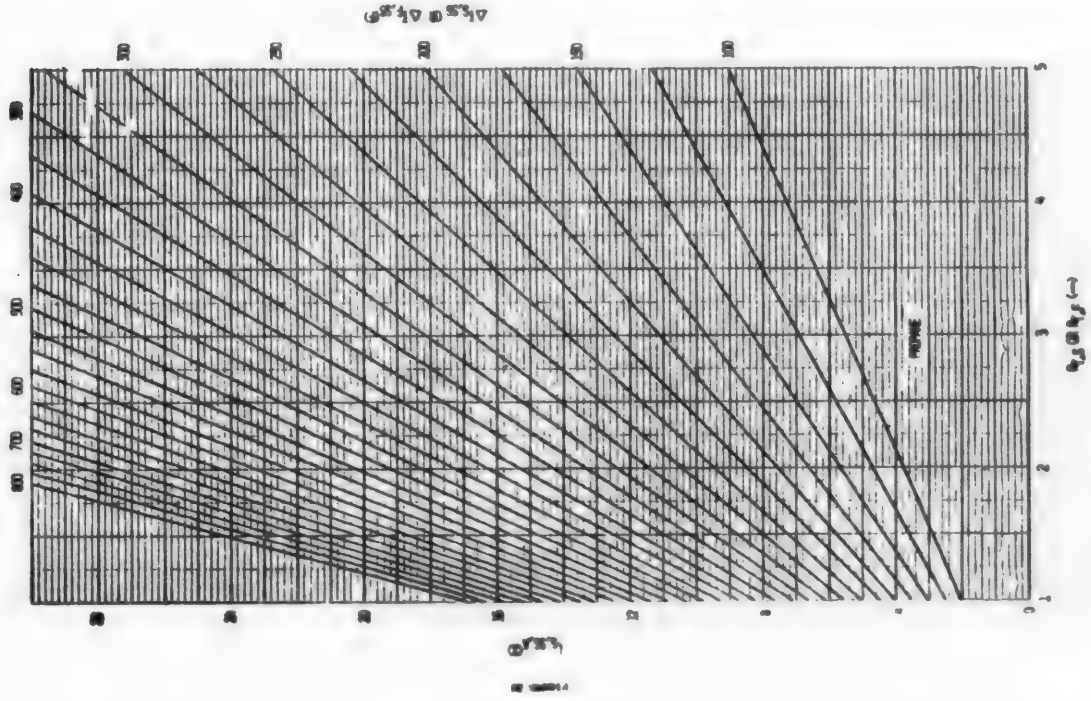


FIGURE 3

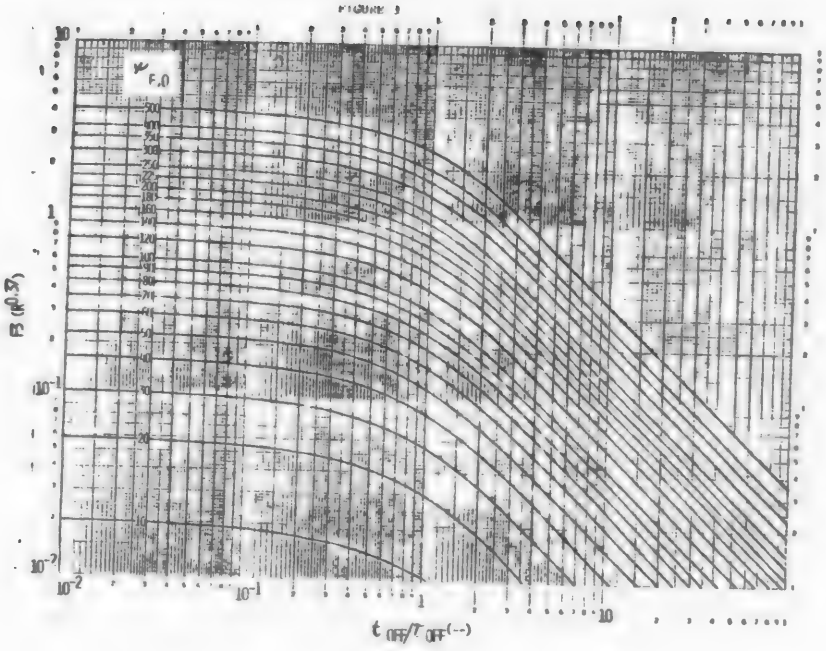
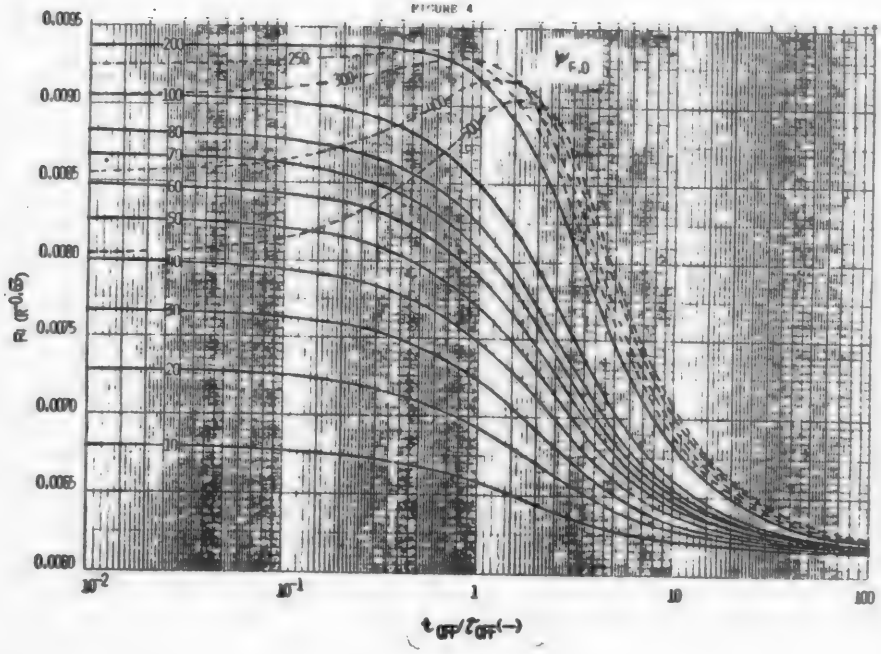
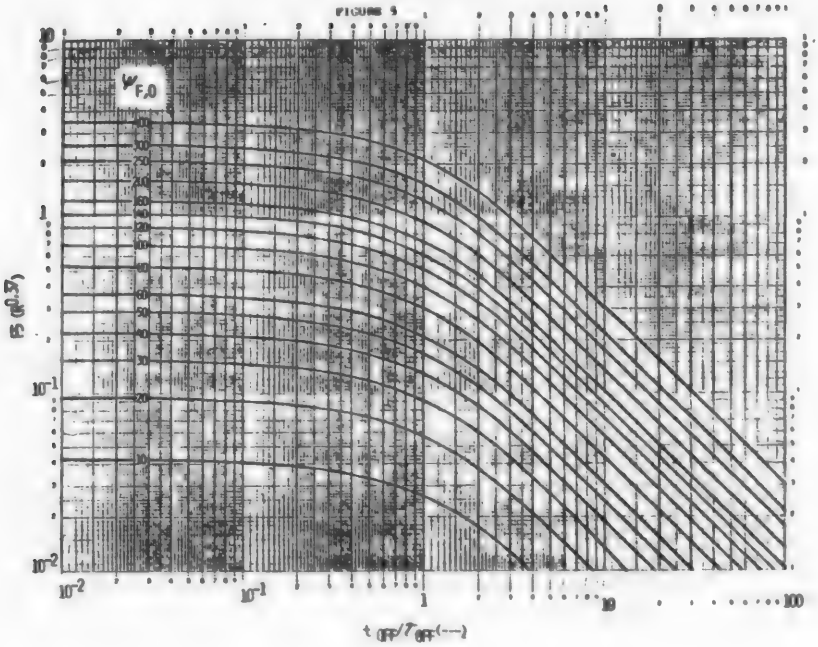


FIGURE 4




$\psi_{F,0}$
$t_{OFF}/\tau_{OFF}(--)$

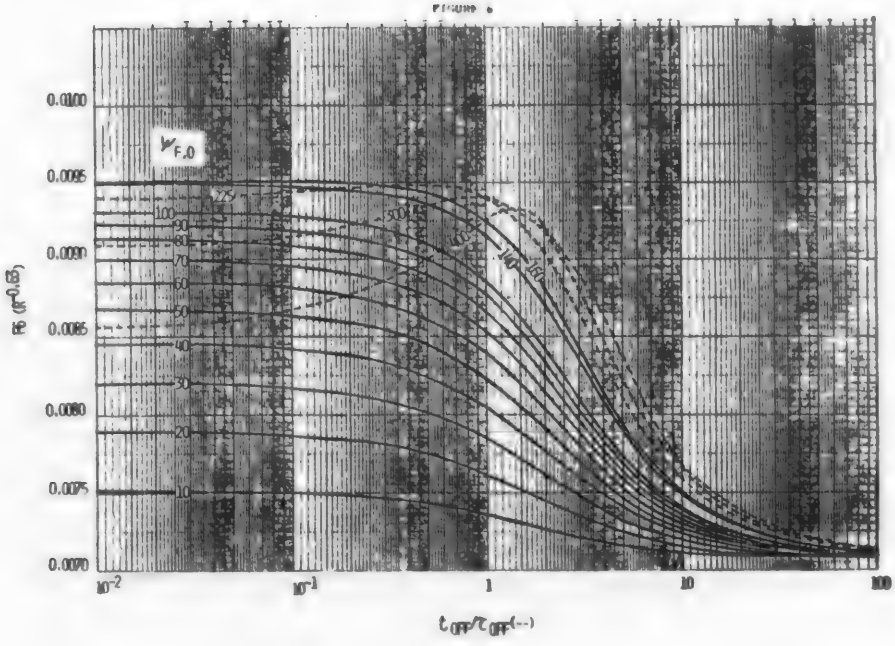

$\psi_{F,0}$
$t_{OFF}/\tau_{OFF}(--)$

FIGURE 7

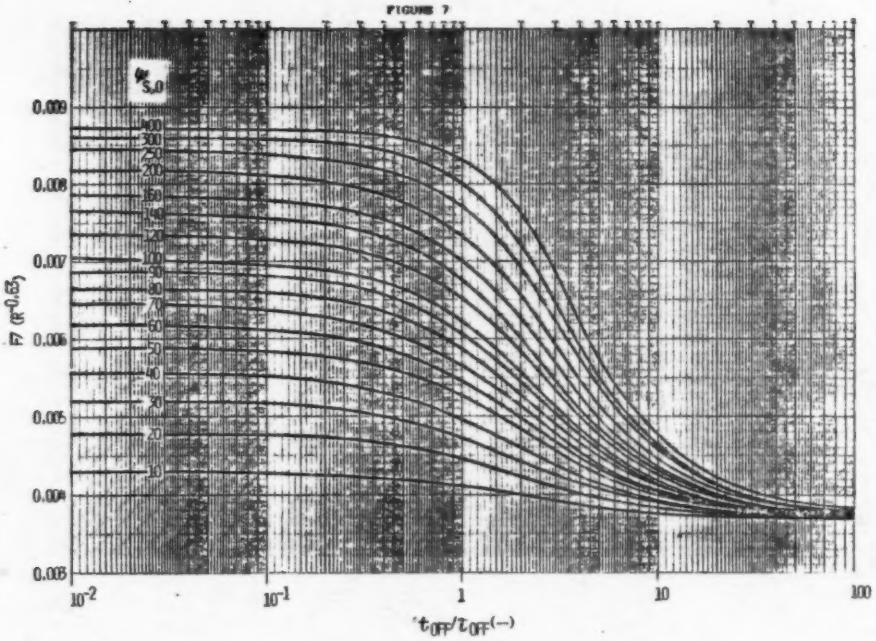


FIGURE 8

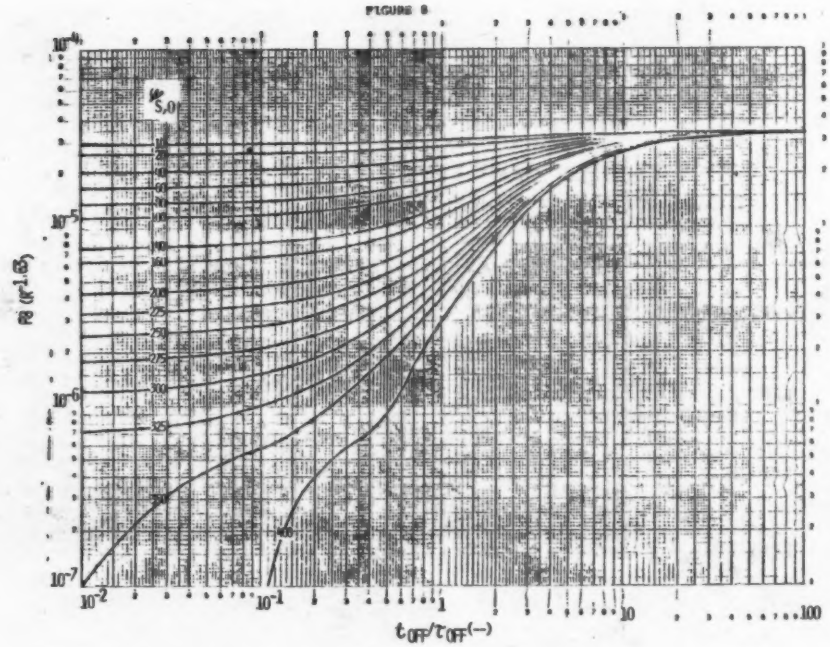


FIGURE 10
WORK SHEET FOR PASSIVE/SOLAR SYSTEMS

Measured Quantities and System Characteristic Constants

1	2	3	4	5	6	7	8	
STAT (-)	STRUC (-)	HDT Btu/lb.	Q_{TD} Btu/hr.	Q_{TD} Btu/hr.	FR hr	AS ft^2	$L_{CO_2,S}$ %	
9	10	11	12	13	14	15	16	
$L_{S,SH,S}$ %	$L_{CC,D}$ %	$L_{T,SH}$ %	$L_{T,SH}(C_1)$ %	$L_{T,SH}(C_2)$ %	$L_{T,OFF}(C_3)$ %	$L_{T,OFF}(C_4)$ %	$L_{T,OFF}$ (%)	
17	18	19	20	21	22			
L_T (-)	S/P (-)	b_p (-)	b_s (-)	* (-)	* (-)			

Derived System Parameters

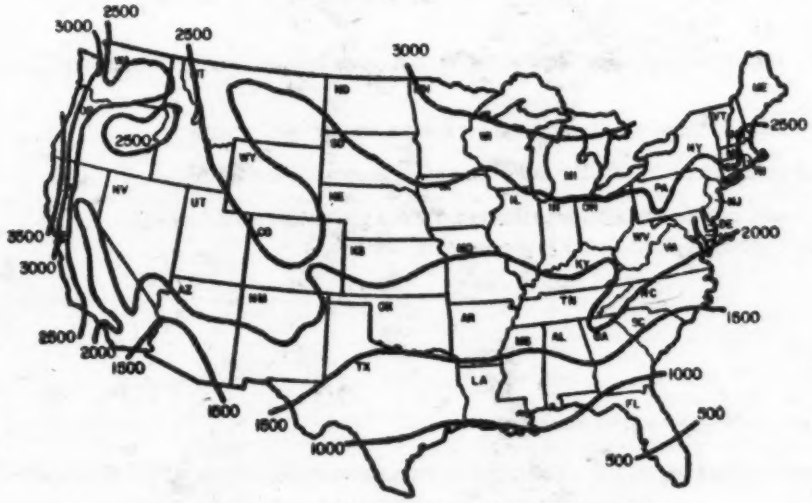
23	24	25	26	27	28	29	30	
HF (-)	HDT Btu/lb.	A/P (-)	$L_{S,A}$ %	L_S %	$h_{s,F}$ (-)	$L_{S,SH}$ %	L_{SH} %	
31	32	33	34	35	36	37	38	
L_{SH} %	L_{OH} minutes	$L_{T,O,S}$ %	L_{OFF} minutes	$L_{T,O,S}$ %	$L_{T,F,S}$ %	$L_{S,Q,S}$ %		
39	40	41	42	43				
L_D (-)	$L_{S,OH}$ (S)/ft	$L_{S,OFF}$ (S)/ft 0.37	$L_{T,OH}$ (S)/ft	$L_{T,OFF}$ (S)/ft 0.37				

Calculation of System Losses and Annual Pool Utilization Efficiency

44	45	46	47	48	49	50	51	
L_{OH} %	L_{OH} minutes	L_{OFF} minutes	L_{OH}/L_{OH} (-)	L_{OFF}/L_{OFF} (-)	$L_{T,O}$ %	$\eta_{T,O}$ %	$\eta_{T,F}$ %	
52	53	54	55	56	57	58	59	
$\eta_{S,O}$ %	$\eta_{S,F}$ %	FS 0.37	FS -0.63	FS 0.37	FS -0.63	FS -0.63	FS -1.63	
60	61	62	63	64	65	66	67	
$L_{S,OH}$ %	$L_{S,OFF}$ %	$L_{T,OH}$ %	$L_{T,OFF}$ %	L_D %	DD *-days	HR hours	EFF_A %	

[FR Doc.77-28068 Filed 9-10-77;11:37 am]

FIGURE 9



This map is reasonably accurate for most parts of the United States but is necessarily highly generalized, and consequently not too accurate in mountainous regions, particularly in the Rockies.

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